UNIVERSITY OF CAPE COAST

NEXUS OF AGRICULTURAL-LAND USE POLICIES AND LANDSCAPE DYNAMICS IN THE RAINFOREST AGRO-ECOLOGICAL ZONE OF GHANA

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BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.. Date:..........................

Name: Wonder Kofi Adzigbli

Supervisors' Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of the thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature:.................................. Date:........................

Name: Prof. Benjamin Kofi Nyarko

ABSTRACT

Despite the positive development, the Rain Forest-Agro-ecological Zone (RFAZ) is characterised by a loss of natural resources and inadequate food security systems. Studies conducted in the Ahanta West Municipality of the RFAZ concentrated on the biophysical features as a drive for landscape changes without highlighting how policies shape landscape dynamics. The study used various methods, including documentary review, structured and in-depth interviews, and geospatial techniques. The study specifically assessed Rubber Outgrower Plantation Project (ROPP) and Norpalm Smallholder Scheme Project (NSSP) due to their deterrent development to the ecological growth of the landscape. The result established that ROPP does not satisfy the conservation pillar of sustainable landscape management. The transitional probability analysis showed that by 2032, the landscape will experience a shift from oil palm farming to rubber cultivation under the economic benefit scenario. Again, oil palm cultivation will be reduced under the social benefit scenario by 15.52%, while there was an increase in the ecological protection scenario (16.83%). The study also identified that crop production, population growth, and land tenure were the main factors that drove the adoption of ROPP and NSSP on the landscape. The results further pointed out that converting croplands to rubber might affect future food security and human well-being. The study recommends that the Food and Agriculture Department of the Ahanta-West district assembly regulate cash crop farmers' activities in the landscape. Land Use and Spatial Planning Authority should also educate farmers on land use decision-making toward rubber cultivation.

KEYWORDS

Policy

Landscape dynamics

Rainforest Agro-ecological Zone

Rain Forest Agro-ecological landscape

Rubber Outgrower Plantation Project

Norpalm Smallholder Plantation project

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DEDICATION

To myself, friends and family

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LIST OF ACRONYMS

CSR	Cooperate Social Responsibility
CVA	Change Vector Analysis
GEP	Ghana Environmental Policy
GREL	Ghana Rubber Estate Limited
GIS	Geographic Information System
GNSDF	Ghana National Spatial Development Framework
GSS	Ghana Statistical Service
HCV	High Conservation Value
LULC	Land Use and Land Cover
MoFA	Ministry of Food and Agriculture
NSSP	Norpalm Smallholder Scheme Project
RFAZ	RainForest Agro-ecological Zone
ROPP	Rubber Outgrowers Plantation Project

CHAPTER ONE

INTRODUCTION

Background to the study

Landscape changes are attributed to human activities around the world, resulting in climate change, biodiversity loss, and material loss in the atmosphere (Gingrich, Magerl, Matej, & Le Noë, 2022; Tiyo, Orach-Meza, & Edroma, 2015). These changes are prominent in the agro ecological zones worldwide, resulting from agricultural industrialisation (Pengui, Manchun, & Liang, 2020). The causes of landscape changes in the agro ecological zones emerge due to inadequate decision-making and implementation of environmental and agricultural policies to protect the physical landscape. According to the Food and Agriculture Organization (2020), agriculture contributes about 4% to the global Gross Domestic Product (GDP), providing significant employment to 884 million (27%) people in the world. Systematisation and economic development result in changes in the agricultural landscape (Kociszewski, 2018).

Despite their poor economic strength, Ghana is one of the few African nations that have adopted international policies in tune with their local policies in managing their natural resources. Policies regarding landscape changes in Ghana have their fundamentals from anthropogenic initiatives that continually change the physical landscape. The agricultural, environmental, and land use planning policies can either improve the physical landscape or hinder the restoration of the environment if not adequately instituted and implemented.

Since independence, agricultural policies in Ghana have been geared towards strengthening the agriculture sector for raw material production for the Western world (Asuming-Brempong, 2013). Interestingly, other policy interventions intending to mechanise and diversify the sector have significantly contributed to cash crop production (Asuming-Brempong, 2013). This led to the development of three model agriculture approaches, which involved the plantation model (involving the devotion of large land parcels to cultivate one specific crop), the out-grower model (involving several farmers producing specific crops under contract and supervision of a mother entity), and cluster model (which involved emerged farmers resulting from the existence of suitable expanse of lands for particular commercial crops cultivation) (Yaro et al., 2018)

A shift in agricultural policies to ensure the industrialisation of the country's economy led to large-scale state farms with mechanised farming approaches differing from the small-scale farming approach. Thus, the Agricultural Development Corporation (ADC) was established to encourage agricultural development by employing modernisation. This led to the expansion of cash crop cultivation in the Western and Brong-Ahafo regions and the motivation of smallholder farmers to form cooperatives to facilitate their access to machinery and modern agriculture extension services (Yaro et al., 2018). The belief in agriculture modernisation, as adopted by Ghana in the post-independence era, was due to the perceived merits of excelling economies in terms of greater productivity and output, technology innovation hubs, and market benefits. These claims have, however, been criticised and opposed (Gyasi, 1992). Among the various factions for such opposition is the reason large-scale plantations disrupt the physical landscape and established reserves. This distortion affects the local community, especially in the plantation zones where large-scale cash crop cultivation occurs. Again, this plantation sometimes deprives local populations of ecosystem services in the ecological system (Daniel, Brass & Bernstein 1992; as cited in Yaro, Teye, & Torvikey, 2016) and food crop production.

Despite all reforms in the agricultural sector through policies, Ghana still lags in achieving the Sustainable Development Goals (SGD), goal 2, which aims to attain zero hunger by 2030. Ghana continues to face challenges in food security nationally due to a decline in agricultural productivity for non-cash crops (Chamberlin, 2007). The situation manifests concern in the Agro-ecological zone of the country as cash crops have begun to dominate the agricultural landscape, raising food security concerns (Boakye, 2015; Ghana Statistical Service, 2014).

The Western Region, located in the Rain Forest Agro-ecological Zone (RFAZ) of Ghana, has raised concerns about how land is rapidly being converted to cash crop cultivation (Ghana faces food insecurity as rubber plantations expand -Alliance for (Science, 2018; Ghana Statistical Service, 2014). Cash crop cultivation, such as rubber and oil palm plantations, can affect both landscapes and potentially impact food crop production, an issue of national concern. Thus, it is vital to understand how the evolution and expansion of cash crop farming over the period have impacted the landscape through agricultural land use policies.

Problem statement

In Ghana, the RFAZ, specifically Ahanta West Municipality, has benefited from vibrant agricultural programs like Rubber Outgrower Plantation Projects (ROPP) and the Norpalm Smallholder Scheme Project

(NSSP). However, the success of these agricultural programs resulted in the increasing size of rubber and oil palm plantations in the Ahanta West District (Agyemang et al., 2018). The success of the agricultural programs has also increased the demand for ecological and croplands for rubber and oil palm plantations. Much research on LULC change in the RFAZ is very general and considers the drivers of LULC changes from biophysical points of view at the national, regional, and district levels; meanwhile, less is known about the direct effect of the policies on the landscape. In the Ahanta West municipality, limited studies were conducted on agricultural-land use policies to evaluate the agricultural land use policies to know their success and failure since their inception. Hence, there is a need to model the interaction between agricultural-land use policies and landscape dynamics in Ghana's Rain Forest Agro-ecological Zone.

Objective of the study

The study's primary objective is to model the interaction between agricultural-land use-related policies and landscape dynamics in Ghana's River Forest Agro-ecological Zone. Specific objectives seek to:

1. Analyse the application of agricultural land use policies in the RFAZ.
2. Examine the impact of agricultural land use policies on the landscape of the RFAZ from 1991 to 2022.
3. Explain the underlying factors accounting for adopting agricultural land use policies in the landscape.
4. Assess the effects of landscape dynamics on food security and Human Well-being (as they relate to the Sustainable Development Goals)

Research question

1. What is the application of agricultural-land use policies in the RFAZ?
2. What is the impact of agricultural-land use policies on the landscape of the RFAZ from 1991 to 2022?
3. What are the underlying factors accounting for the adoption of agricultural-land use policies in the landscape?
4. What are the effects of landscape dynamics on food security and Human Well-being?

Significance of the study

This study would help to achieve sustainable development goal 15, which aims to protect life on land. First, understanding the rate of change in land cover will help inform physical plans in Ghana. Secondly, armed with the causes of landscape dynamics, policymakers can better be informed to adjust and make policies on the development and usage of RFAZ. Lastly, results on the state of the landscape of the RFAZ in the year 2032 can help spearhead the agenda for sustainability. Educators can specifically enlighten the agriculture sector and government on policies that must be implemented to conserve the agriculture landscape. It will also enhance the sustainability of the ecosystem and the well-being of the local communities in the RFAZ.

Delimitations

The study was limited to RFAZ of Ghana, specifically Ahanta west Municipality in the Western Region. This is due to its specific characteristics, consequently supporting various cash or industrial crops cultivated in the region. Also, the landscape analysis was limited to LULC. In doing so, the study models the future state of land cover. The natural variables in the model were limited to topographic parameters such as slope, elevation and aspect. The study was limited to rubber and oil palm farmers who were beneficiaries of either ROPP or NSSP in the Ahanta West Municipal.

Organisation of the study

This research was made up of five chapters. The first chapter dwells on the introduction, which includes a brief background about the research topic. It also discussed the problem statement, research questions, delimitations and significance of the study.

Chapter Two reviews relevant literature. This was divided into three: conceptual, theoretical, and empirical literature. These emphasise issues related to the research topic, like agriculture policies in Ghana, the impact of agricultural policies on landscape changes, and related studies. Chapter Three also dwells on the methodology, divided into three main areas. These include the research design, data source, and description and procedures of analysis. Chapters Four to Seven also cover the presentation, analysis, and discussion of the data about the literature. Chapter Eight finally summarises the major findings, concludes, and offers suggestions based on the study's findings.

CHAPTER TWO

LITERATURE REVIEW

Introduction

This chapter aims to introduce and explore vital knowledge about agricultural policies and landscapes. The chapter covers definitions of agriculture policies and landscape dynamics. Further, the chapter reviews the literature on the role of geospatial technology and spatial modelling in land use mapping. Again, the chapter elaborates on the Driver-Pressure-State-Impact-Response (DPSIR) framework to help conceptualise the relevant variables for the study. This chapter also expounds on the theory underlying this study, namely socio-ecological systems theory, which employs a holistic human-in-nature approach to addressing problems. Finally, the chapter also covers relevant literature on the implication of landscape dynamics on food security, insecurity, and livelihood in the RFAZ.

Agricultural policies

Agricultural policies refer to laws relating to domestic agriculture and importing foreign agricultural products (Josling, 2019). According to Hill (2018), agricultural policies examine the relationship between agricultural economics and society. Thus, it mediates the relationship between farming sectors, the environment, and society. The concept of agriculture policies examines how government laws and agriculture programmes affect the landscape's spatial extent (Spangler, Burchfield, & Schumacher, 2020). Agriculture policies could be the sectoral or global base that tends to achieve the mandate of monitoring and regulating agricultural activities on the landscape. Agricultural policies are developed to fulfil a long-term national strategy (Bruinsma, 2017), but they keep changing dramatically, particularly in Africa and Latin America. Further, FAO (2020) states that agriculture policies have contributed to about 38% of the world's land surface.

In the context of this study, agricultural policies may refer to agricultural projects, programmes, or interventions rolled out in the RFAZ landscape. This project focuses intensely on cash crop production, specifically rubber and oil palm production as an industrial crop for export. The project serves as policy because it opens job avenues for numerous habitats in the RFAZ in different dimensions. Two major agricultural projects were undertaken in the landscape: the Rubber Out Growers Plantation Project (ROPP) and the Norpalm Smallholder's Scheme Project (NSSP).

Types of Agriculture Policies

In many countries, agriculture forms a significant sector of their economy. In order to strengthen these economies, governments have implemented various policies to support and promote the development of this sector. There are five types of agricultural policies, namely, price support policies, input subsidy policies, trade policies, rural development policies, and environmental policies.

Price-support policies

Price support policies involve setting minimum prices for agricultural products. Governments may offer subsidies or other incentives to encourage farmers to produce crops that are in high demand. These policies aim to stabilise prices, ensure adequate food supplies, and provide a fair return to farmers.

Input subsidy policies

Input subsidy policies provide farmers with fertilisers, seeds, and pesticide subsidies. These policies aim to improve agricultural productivity, reduce production costs, and increase food production (Jayne et al., 2018). Input subsidy policies can increase agricultural productivity and food production but may also lead to overuse of inputs and environmental degradation.

Trade Policies

Trade policies involve tariffs, quotas, and subsidies to regulate imports and exports of agricultural products. These policies protect agriculture from foreign competition and ensure a fair market. It also leads to higher consumer prices and reduced access to international markets for farmers.

Rural development policies

Rural development policies provide infrastructure and services such as roads, electricity, and healthcare to improve rural communities' living standards.

Environmental policies

Environmental policies involve measures to protect the environment and natural resources. These policies may include regulations on using pesticides and fertilisers, soil and water resources conservation, and promoting sustainable agricultural practices. These policies aim to promote sustainable agriculture and reduce environmental damage (Pannell et al., 2018).

Importance of agriculture policies

Agriculture policies play a significant role in enhancing food security, which is critical to sustainable development. According to Di Falco et al.

(2019), agriculture policies can support smallholder farmers by providing them with resources such as fertilisers, seeds, and extension services, increasing their productivity and income. Furthermore, agriculture policies can reduce market imperfections, such as price volatility and inadequate infrastructure, limiting consumers' food access. Agriculture policies promote rural development by supporting smallholder farmers, improving rural infrastructure, and promoting value chains. According to Jaleta et al. (2021), agriculture policies that support smallholder farmers can reduce poverty and create employment opportunities in rural areas.

Furthermore, investments in rural infrastructure, such as roads, water, and electricity, can improve access to markets, reduce transaction costs, and increase the competitiveness of rural products. Moreover, promoting value chains, such as agro-processing and marketing, can increase value addition and provide additional income opportunities for rural communities. Agriculture policies can also address climate change by promoting sustainable agricultural practices that reduce greenhouse gas emissions and enhance resilience to climate shocks. According to Tubiello et al. (2014), agriculture policies can promote climate-smart agriculture, which involves adopting sustainable practices such as conservation agriculture, agroforestry, and livestock management. Furthermore, agriculture policies can support the development and disseminating of climate-resilient crop varieties and livestock breeds.

Effects of agricultural policies

Agriculture policies are critical components of a country's development strategy. Policies implemented to support agricultural productivity and growth have positively affected economic growth, poverty reduction, and food security. However, these policies can also have negative impacts, such as environmental degradation and social inequality.

Positive Effects

Agriculture policies have been shown to affect economic growth positively in many countries. In a study of 42 African countries, Osabouhien (2022) found that agricultural policies, such as investment in rural infrastructure and agricultural research and development, significantly affected economic growth. Another study by Kym Anderson (2019) found that agricultural productivity has driven economic growth in developing countries over the past few decades. Agriculture policies can also have positive effects on poverty reduction. In a study of rural households in Nepal, Shrestha et al. (2022) found that government policies that support agricultural production and marketing positively impact income, reducing poverty.

Similarly, a study by Diao and colleagues (2019) found that agriculture investments can reduce poverty by increasing agricultural productivity and creating employment opportunities in rural areas. Agriculture policies can also play a crucial role in achieving food security. In a study of 44 African countries, Okpara and colleagues (2017) found that policies aimed at improving agricultural productivity, such as investments in research and development and extension services, positively affected food security. Similarly, Fan et al. (2017) found that investments in irrigation infrastructure and rural roads can improve food security by increasing market access and reducing food losses.

Negative Effect

Agriculture policies can also have negative impacts on the environment. In a study of the Brazilian Amazon, Nepstad et al. (2014) found that government policies promoting agricultural expansion had led to significant deforestation and environmental degradation. Similarly, a study by Asfaw et al. (2020) found that agricultural policies aimed at increasing production can lead to land degradation and the depletion of natural resources. Agriculture policies can also have implications for social inequality. In a study of Mexico, Aparicio et al. (2012) found that government policies that support large-scale agricultural production have led to increased land concentration, which exacerbates social inequality. Similarly, a study by Doss (2017) found that women are often excluded from accessing agricultural resources and benefits, which can perpetuate gender inequalities.

Agricultural-Land Use Policies Review

This section reviews agricultural-land use policies in the Rain Forest Agro-ecological Zone from 1995 to 2022. These policies include the Rubber Outgrower Plantation Project (1995–2022), the Norpalm Smallholder Scheme Project (1996–2021), the National Environmental Policy (1995–Present), and the National Environmental Policy (1995–Present).

Rubber Outgrower Plantation Project (1995–2022). To encourage economic empowerment and development in rubber farming in the RFAZ, the government of Ghana established the ROPP in 1995. The objective of the ROPP is to develop rubber as an industrial crop in Ghana while at the same time promoting best farming practices in rubber farming. It also helped farmers develop clonal rubber plantations. GREL coordinates the ROPP with the Agricultural Development Bank (ADB) and the National Investment Bank (NIB). The ROPP was also financed by international organisations such as the *Agence Française de Développement* (AFD) and the World Bank, which use a contract farming scheme. The scheme has a tripartite structure that involves GREL as the buyer and the Rubber Outgrowers Agents Association (ROAA) with financial support from ADB as producers. The ADB provides long-term loans to smallholder farmers to cultivate and rehabilitate rubber plantations. According to FAO (2021), smallholder farmers must deliver the latex rubber to GREL to pay for the planting materials under the tripartite contract.

The purpose of the development of rubber was to help improve farmers' income and alleviate poverty in rural areas (Lisa & Roble, 2012). ROPP intends to provide high-quality extension services to rubber out-growers using advanced and innovative technologies in rubber plantation farming across the ecological zone. The project was undertaken in phases to help implement sustainable cultivation strategies in rubber production. The project's first phase lasted from 1995 to 1999, while the second phase was launched in 2000. The project spearheaded the cultivation of rubber plantations, thus increasing the hectares of rubber plantations over the period. According to Li (2022), 400 outgrow planters over 1200 hectares of rubber plantation from 1995 to 1999 contributed to changes in the agricultural landscape. Though the project policies targeted the economic independence of cash crop farmers in the RFAZ, agricultural landscapes are susceptible to human influences and disturbances. The financial support from these donors has helped encourage more farmers into rubber plantations, expanding farm sizes and changing the rubber-dominant plantation landscape.

Norpalm Smallholder Scheme Project (1996-2021)

The NSSP is a smallholder plan that covers about 2,471 acres of land to guarantee a constant supply of oil palm bunches at a lower operational cost to the business. The scheme started in 1996 to provide a livelihood to the farmers. The scheme piloted about 278 acres of land with 40 smallholder farmers from four (4) major oil palm growing communities. These communities include Ewusiejoe, Mpohor, Ahanta Yabiw, and Bokoro. The programme was open to all residents of these communities except for natives who worked for the Norpalm oil company. The company gave the smallholders a loan over five years as part of their agreement with the corporation to develop six acres of land for each farmer. The basic requirement for participation in the scheme was accessibility to land. The scheme provided access to labour, cover crop seeds, oil palm seedlings, equipment, and agrochemicals such as herbicides, fertilisers, and insecticides as part of the contract with smallholder farmers. The scheme also facilitates the transportation of oil palm bunches from the farms to the Norpalm processing mill. The NSSP operates by providing financial support to smallholder farmers. The deduction varies from farmer to farmer and is based on the inputs, farming techniques, and the overall volume of palm fruits collected. For instance, the cost of fertiliser is subtracted over a year, while the cost of weeding is subtracted over four months. The smallholders would own the farm for 25 years, the length of an oil palm tree's economic life. The Norpalm oil company follows the World Bank-established pricing structure, whereby oil palm bunches are purchased for about 10% of the global market price of crude palm oil. This indicates that the price for the oil palm bunches has no bearing on the smallholders.

National Environmental Policy (1995–Present)

The national environmental policy was established in 1995, just after the establishment of Ghana's constitution in 1992—the policy aimed to manage the environment to sustain society at large. The goal of the policy is to bring Ghanaians together in the pursuit of a society where all citizens have access to enough healthy food, clean air and water, decent housing, and other necessities that will make it possible for them to coexist peacefully with their natural surroundings on a spiritual, cultural, and physical level. The policy promotes sustainable agriculture by ensuring sustainable land use in the agricultural economy. Environmental policy also promotes and encourages low-farming systems. The policy also targets the protection of forest and wildlife resources and the conservation of biodiversity and ecosystems through the engagement of local communities in and around protected areas. The policies also strengthen job creation in urban areas. The environmental policy operates with various sectors in Ghana to ensure sustainable land management.

Ghana National Spatial Development Framework 2015–2035

The GNSDF is a long-term spatial development plan from 2015 to 2035 to accelerate spatial development in Ghana. The GNSDF was created in collaboration with the Ministry of Lands and Natural Resources (MLNR), the Ministry of Environment, Science, Technology, and Innovation (MESTI), the Land Use and Spatial Planning Authority (LUSPA), and the National Development Planning Commission (NDPC). The GNSDF was developed with input from the first Medium-Term National Development Policy Frameworks and GSGDAs I and II. It also cushions inputs from sectoral plans and policies in the economy, transportation, education, health, environment, energy, climate change, and land use. The policy also relied on input from several national, regional, and district government agencies. The framework is anticipated to contribute to the National Long-Term Development Strategy while assisting local governments in preparing regional, subregional, and district spatial development frameworks and lower-level plans. The GNSDF is divided into three volumes: (i) the circumstances and major issues, (ii) general strategy, and (iii) framework implementation. GNSDF has five primary goals. Thus, priority should be given to balanced polycentric growth; regional, national, and international connections should be improved; boost the metropolitan cities of Accra and Kumasi; encourage growth in networks and secondary cities; and ensure long-term development and the preservation of natural resources.

The GNSDF establishes a place-based framework that includes an urban settlement hierarchy, a megaregion combining several large urban centres in the ECOWAS region. This linear, two-city region has taken on a larger scale than individual large cities (Accra and Kumasi) and eight urban networks. The policy suggests an overarching concentrated development policy, which comprises the following essential initiatives to be implemented: increase awareness of the Accra Capital Region and encourage current urban communities while discouraging new ones. Encourage bigger settlements while discouraging smaller ones; encourage urban development along important transportation lines. Plan for the incorporation of rural towns into growing urban regions. Prevent settlement development on agricultural land and woods. Maintain and improve the primary motorway network's efficiency. The GNSDF has set out to accomplish ten national projects under its policies between 2015 and 2035. These projects include a national and international highway network, renovated and upgraded trunk roads, a rail network that is both national and international in scope, four international airports, a new airport city in the triangle's centre, three new seaport options, a network of green infrastructure, an agricultural expansion corridor, proposed urban foodsheds, and projects involving alternative energy.

Policy Evaluation

Policy assessment reviews the efficacy of government policies, initiatives, and interventions to evaluate if they produce the desired results (Berman, 2018). Evaluation of policies is essential for maintaining accountability, identifying improvement opportunities, and informing future policy decisions. Thus, it is an essential instrument for evaluating the efficacy of government policies and programs. Agricultural and land-use policies significantly impact the development of rural areas and food systems. Evaluation of policies is vital for determining their efficacy and effects. Agricultural and land use policy analyses have yielded several noteworthy results. First, it has been discovered that policies supporting sustainable agriculture practices, such as conservation tillage and crop rotation, increase soil quality and prevent erosion (Lal, 2015). Moreover, policies that promote the adoption of precision agriculture technologies, such as GPS-guided tractors and drones, have been demonstrated to boost crop yields and decrease input costs (Braunack & Hardaker, 2019).

Secondly, agricultural policies that assist small-scale farmers, such as subsidies and access to financing, have been demonstrated to increase their income and quality of life (Gao & Xu, 2018). Moreover, it has been demonstrated that policies encouraging gender equality and women's engagement in agriculture increase production and improve food security (FAO, 2018). Thirdly, it has been discovered that land use policies that promote the preservation of natural habitats, such as wetlands and forests, increase biodiversity and offer ecosystem services (Gardner et al., 2013). In addition, strategies that promote agroforestry, such as incorporating trees into agriculture and animal systems, have increased soil fertility, boosted crop yields, and brought additional advantages (Garrity et al., 2010). Environmental measures, such as emission regulations, can enhance air quality and lower the prevalence of respiratory sickness (Dockery et al., 1993).

Approaches for policy evaluation

Policy evaluation employs numerous methodologies, including quantitative and qualitative methods, mixed-methods, and experimental designs. The randomised controlled trial (RCT), which involves randomly assigning people to a treatment group that receives the policy intervention and a control group that does not, is one of the most commonly used methodologies. Without random assignment, the quasi-experimental design compares the outcomes of groups that got the policy intervention to those that did not (Shadish, Cook, & Campbell, 2002). There are numerous ways of evaluating policies, such as experimental and quasi-experimental designs.

Challenges of policy evaluation

The evaluation of policies presents numerous obstacles. Identifying the proper outcomes to measure is one of the primary obstacles. Policies may have unexpected repercussions, and it can be challenging to discern which outcomes are related to the policy and which are not (Rossi, Lipsey, & Freeman, 2004). The difficulty quantifying the long-term effects of initiatives is an additional obstacle, or vice versa; policies may have short-term advantages but long-term drawbacks (Greenberg, 2005). Despite the difficulties associated with policy evaluation, numerous examples of policies have been demonstrated to help enhance results in a range of policy domains. Policymakers can use the findings of policy evaluation research to guide future policy decisions and enhance the well-being of their constituents. In conclusion, policy evaluation ensures that agricultural and land use policies effectively achieve their objectives. Policy reviews have yielded several important conclusions, including the importance of sustainable agriculture methods, policies to assist small-scale farmers, and land protection measures.

Landscape dynamics

According to Turner, Gardner, and O'Neill (2001), landscape dynamics refers to changes in a landscape's physical, biological, and social characteristics over time. It is also defined as the processes that shape and change the physical features of the landscape. These processes include natural and human forces such as erosion and weathering, land development, and farming. The knowledge of landscape dynamics enabled us to predict the impact of climate change, manage natural resources, and preserve habitats (Wiens, Milne, & Ricketts, 1995). Climate, geology, biology, and human activity were a few of the factors that influenced landscape dynamics. According to Muñoz-Torrent, Trindade, and Mikulane (2022), human activities have caused 80% of the change in the landscape through land development, such as clearing trees and vegetation, construction of roads, and building, among others. In agriculture, landscape changes from crops and livestock can alter the composition and structure of the soil. Natural phenomena like climate change can affect landscape changes through erosion, which occurs when water, wind, or ice disappears at the land's surface.

Again, geology can also play a significant role in landscape changes, as the type of rock or soil in a particular location can affect how easy it is to erode or hold up to weathering in that area. Biologically, the landscape of a particular area changes as plants and animals continually shape the features of the landscape through their activities. Weins et al. (1995) pointed out that landscape dynamics enable us to understand the processes that shape and change the earth's surface; hence, it allows us to make informed decisions about the planning and management of natural resources. Singh, Venkatramanan, and Deshmukh (2022) also posit that understanding landscape dynamics is vital for predicting and monitoring changes in a given environment to ensure a sustainable environment and human habitats.

Causes of landscape dynamics

The causes of landscape dynamics result from various natural and anthropogenic factors, including climate change, land use practices, and disturbances such as fire, flooding, and human activities. Climate change is one of the primary drivers of landscape dynamics globally. Temperature and precipitation patterns can alter vegetation composition, distribution, and productivity. For instance, in the Arctic, warming temperatures are causing the permafrost to thaw, leading to changes in vegetation patterns and soil properties (Hinzman et al., 2005). Similarly, droughts and heat waves have led to tree mortality and forest dieback in many parts of the world, including the Amazon Basin (Phillips et al., 2009). Land use change, particularly converting natural ecosystems to croplands or urban areas, is another primary driver of landscape dynamics. Agricultural practices such as intensive farming and monoculture can lead to soil degradation, nutrient depletion, and biodiversity loss (Tilman et al., 2002). Urbanisation can lead to habitat fragmentation, the loss of green spaces, and altered microclimates (Grimm et al., 2008).

Disturbances like fire, flooding, and human activities can cause landscape dynamics. Fire is a natural disturbance in many ecosystems, but changes in fire regimes can significantly impact vegetation composition and structure (Bowman et al., 2009). Flooding can alter riverine and wetland ecosystems, leading to changes in hydrology and nutrient cycling (Junk et al., 1989). Human activities such as logging, mining, and infrastructure development can cause significant landscape changes, including deforestation, soil erosion, and habitat loss (Laurance et al., 2011). Invasive species are non-native species that can cause significant changes in ecosystem structure and function. Invasive species can outcompete native species, alter nutrient cycling, and impact ecosystem services such as water filtration and carbon sequestration (Mack et al., 2000). Invasive species can also increase the frequency and intensity of wildfires in some ecosystems (Brooks et al., 2004).

Effects of landscape dynamics

Landscape dynamics is a complex process involving the interactions between an ecosystem's biotic and abiotic components. It encompasses changes in land cover, land use, and other factors that shape the structure and function of ecosystems. Landscape dynamics can significantly impact biodiversity by altering the structure and connectivity of habitats. Fragmentation of habitats due to land-use changes can lead to species loss, genetic diversity and changes in species composition (Fahrig 2003). In contrast, creating new habitats through land-use changes can provide opportunities for colonisation by new species and increase overall biodiversity (Tscharntke et al. 2012).

Furthermore, landscape dynamics can affect species' distribution and abundance by altering resource availability and habitat suitability (Kissling et al., 2012). Landscape dynamics can also significantly affect ecosystem services, which are the benefits humans derive from ecosystems. For example, land-use changes can affect water flow, nutrient cycling regulation, and critical ecosystem services (Foley et al. 2005). Changes in land cover can also affect the provision of cultural services, such as recreational opportunities and aesthetic values (Millennium Ecosystem Assessment, 2005). Landscape dynamics can influence various ecological processes, such as primary productivity, nutrient cycling, and carbon sequestration. Changes in land use, such as the conversion of forests to agriculture, can affect the rate and efficiency of these processes (Houghton et al. 2012). Landscape dynamics can also affect the resilience of ecosystems to disturbances such as climate change and natural disasters (Gunderson and Holling, 2002).

Models for assessing landscape dynamics.

Land use and land cover changes (LULCC) substantially affect natural resources and human communities. Understanding the causes and patterns of LULCC is crucial for influencing land management policies and strategies for sustainable development. This literature review gives an overview of the models used to analyse LULCC, including their strengths and limitations, and highlights some of the most significant research discoveries on this subject. Various models are available for evaluating LULCC, including empirical, dynamic, and agent-based models. Environmental and socioeconomic variables and LULCC patterns are statistically related in empirical models (Lambin & Geist, 2006). Mathematical approaches simulate the spatial and temporal dynamics of LULCC using dynamic models, such as cellular automata and Markov models (Verburg et al., 2002). Agent-based models use the decision-making processes of individual actors, such as landowners or farmers, to determine LULCC trends (Parker, 2002).

Strengths and limitations of landscape dynamics models

Each model has its advantages and disadvantages. Empirical models are simple to develop and can represent the spatial and temporal patterns of LULCC, but they fail to account for the processes underlying LULCC (Dale et al., 2010). Dynamic models may evaluate the effects of alternative policy scenarios on LULCC patterns, but they are computationally costly and require extensive data on land use change drivers (Pontius Jr. & Millones, 2011). Agent-based models can represent the variety of LULCC decision-making processes and social contexts, but they are data-intensive and challenging to execute (Parker et al., 2002). Much research has been conducted on LULCC modelling, spanning numerous locations and land use types. In many regions, land use intensification and urbanisation are the primary drivers of LULCC, resulting in habitat fragmentation, biodiversity loss, and alterations to hydrological cycles (Foley et al., 2005). Policy interventions, such as conservation incentives or land use limitations, can considerably affect LULCC trends (Lambin et al., 2001).

LULCC modelling can be used to anticipate the effects of climate change on land use and land cover patterns, such as agricultural production and water availability changes (Veldkamp & Fresco, 1996). Integrating several models, such as empirical and dynamic models, can enhance the precision of LULCC forecasts and inform policy decisions (Dale et al., 2010). Understanding the sources and patterns of land use change and guiding land management policy and sustainable development plans requires LULCC modelling. Each model has advantages and disadvantages, and the selection of a model depends on the study issue and the available data. Notwithstanding the difficulties associated with LULCC modelling, several examples of practical uses exist in various geographies and land use patterns. The results of LULCC modelling studies can guide land management policies that balance economic development and environmental sustainability.

Modelling landscape dynamics using the Markov and S-Clues models

A Markov statistical model uses probability transition matrices to describe the probability of a particular state (land cover class) changing to another state over time (Hamad, Balzter, & Kolo, 2018). In the context of land cover change modelling, a Markov model can be used to predict the future land cover of a region based on its current land cover and the probabilities of different land cover classes changing over time (Hamad, Balzter, & Kolo, 2018). This model is beneficial for capturing short-term changes in land cover, as it assumes that the future state of the landscape is only dependent on its current state (Hamad, Balzter, & Kolo, 2018).

The S-CLUES (Spatially Explicit Conceptual Land Use and Environmental Simulation) model, on the other hand, is a rule-based model that uses a set of predefined rules to simulate the dynamics of land use and land cover changes (Li, Zhang, Fan, & Li, 2011). Unlike Markov models, S-CLUES models consider the spatial and temporal relationships between land cover classes and the interactions between human activities and the physical environment. The S-CLUES models are often used to simulate the long-term effects of land use and land cover changes on landscapes and evaluate the impact of different policy scenarios on land use and land cover changes (Li et al., 2011). In conclusion, both Markov models and S-CLUES models have their strengths and weaknesses, and the choice of which model to use will depend on the specific goals and objectives of the land cover change modelling.

Agriculture, policies, and landscape change

Agriculture policies can impact landscape dynamics in various ways. For instance, subsidy programmes can incentivise farmers to expand their agricultural lands, leading to deforestation and biodiversity loss (Reidsma et al., 2018). In contrast, conservation policies can encourage farmers to adopt sustainable practices such as crop diversification and agroforestry, enhancing landscape biodiversity (Tilman et al., 2017). Several studies have examined the effectiveness of different agricultural policies in achieving landscape sustainability. For example, Van Vliet et al. (2016) found that Payments for Ecosystem Services (PES) schemes can promote sustainable land use practices among farmers. PES schemes provide financial incentives to farmers who adopt practices that enhance ecosystem services, such as carbon sequestration and water quality improvement.

Similarly, Wu et al. (2021) found that land use zoning policies can effectively regulate land use changes and promote landscape sustainability. Several factors can affect how successful agricultural policies are at achieving landscape sustainability. For instance, farmers' socioeconomic and cultural context can affect their willingness to adopt sustainable practices (Van der Ploeg et al., 2016). Similarly, the governance structure and institutional arrangements of policy implementation can impact the outcomes of agricultural policies (Boonstra et al., 2019).

The conceptual model for the study

Socio-ecological systems theory supports the conceptual framework for this study. The Driver-Pressure-State-Impact-Response (DPSIR) framework was used in this study. It was based on work by Buck et al. (2006) and the EEA technical report on environmental indicators from 1999 (see Figure 1).

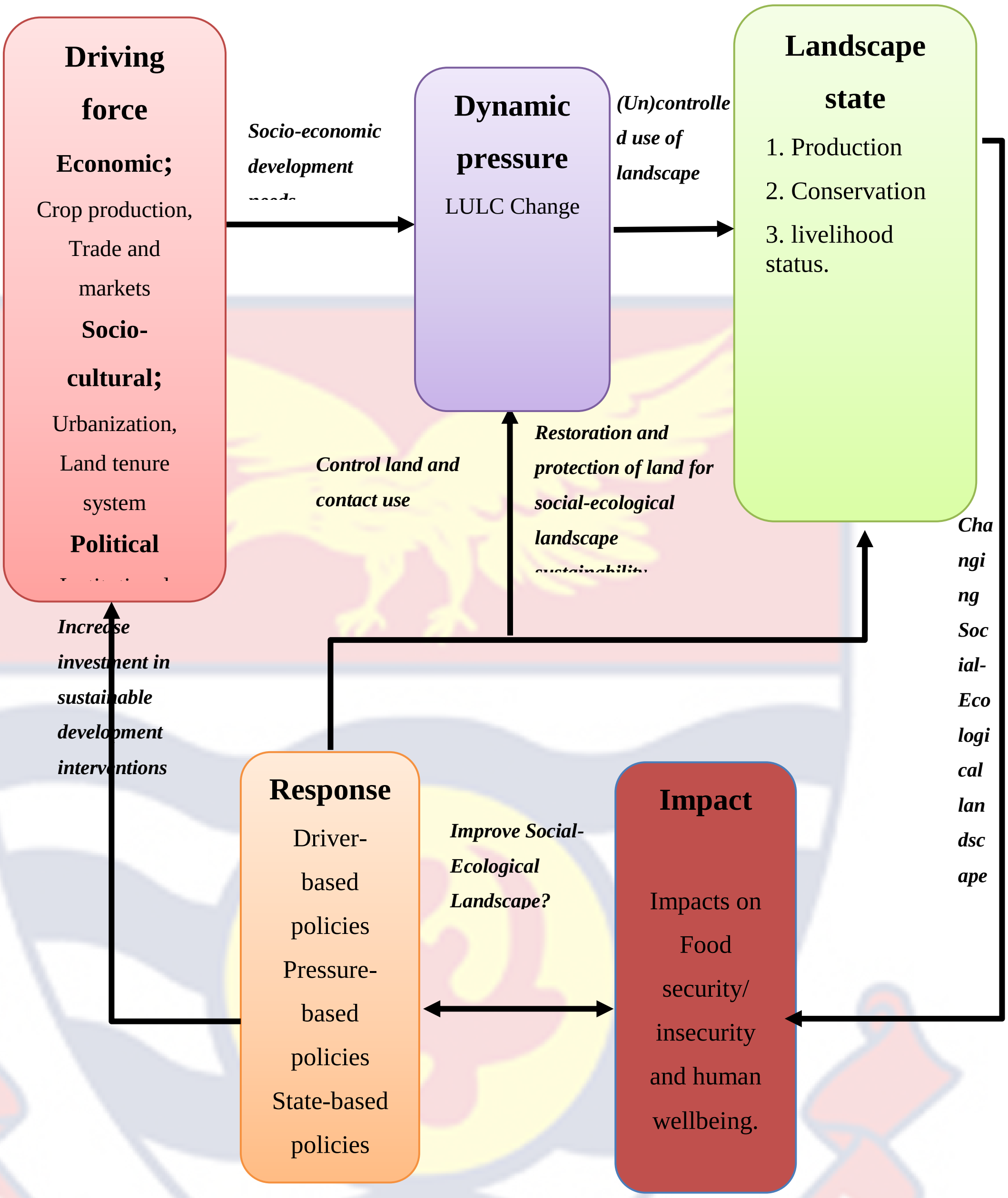


Figure 1: Driver- Pressure-State-Impact-Response (DPSIR) framework
Source: Adapted from EEA (1999)

The socio-ecological system is a complex integrated system of relationships between social (human) and ecological (biophysical) subsystems, which helps to identify and describe processes and interactions in human-environmental systems. Again, it enables the analysis of specific cause-and-effect relationships in the past, recent, and future developments. It also provides a reasonable basis for explaining mainly environmental issues

(Ahmed, Mahmud, & Sohel, 2021). The framework serves as an improved understanding of indicators for and appropriate responses to the impacts of human activities on the environment along the causal chain (Eurostat, 1999, as cited in Binder, Hinkel, Bots, & Pahl-Wostl, 2013). Though the framework overly simplifies the "real world," it helps build a conceptual understanding of the relationships between environmental change, anthropogenic pressures, and management options (Smith et al., 2014). This framework categorises all relevant variables under either driver, pressure, state, impact, or response. These categories are explained as follows:

Driving forces

Drivers or driving forces refer to the various factors that cause changes or lead to the behaviour of a system. These factors can be natural or human-induced and are not very flexible or reactive to changes in the rest of the system but instead describe current conditions and trends. They are thus considered the government's overarching economic and social policies and the economic and social goals of those involved in the industry. Drivers have been functionally segregated into economic, social-cultural, political, or institutional drivers. In the context of this study, economic drivers include the production of cash crops, the availability of trade, and the market for cash crops. The sociocultural drivers in the study refer to demographic dynamics such as urbanisation and land tenure systems, which may influence the sustainability of agricultural policies. Finally, political drivers involve institutional arrangements supporting cash crop cultivation in the RFAZ. The institutional arrangement may be a collaboration between policy implementers and financial institutions that support the policies. The drivers have an apparent influence on the system by altering the conditions of the system.

Dynamic pressure

Pressure refers to human activities derived from functioning social and economic driving forces that induce environmental or human systems changes. Pressure indicators are the mechanisms by which action has an actual or potential effect on any part of the ecosystem. They express the consequences of various actions resulting from patterns of driving forces. The dynamic pressure of the landscape is measured through the changes in the LULC of an area over time resulting from the alteration of the natural landscape. The LULC change enabled us to identify which part of the landscape is undergoing a change and the pressures influencing the changing nature of the land. Thus, dynamic pressure is a result of specific causes of action acting on the landscape. For instance, anthropogenic factors (economic, socio-cultural, and political) increase changes in the LULC persistently.

Landscape state

The framework's landscape state component or indicator refers to the results of dynamic pressures (actions) on the landscape. It looks at the state of both the natural and built environments. According to Lewandowski and Cates (2022), the state provides information on the quantity and quality of physical, chemical, biological, and human systems. In the view of this study, the landscape state looks at the state of agriculture systems, ecosystems and services, livelihoods, and institutional policies. The explanation for this indicator takes two perspectives: natural science and social science. According to Smith et al. (2014), the natural science perspective interprets "state" to be the state of the environment, while the social science perspective interprets it as state change (of the environment). Some of these changes are abrupt, while others are relatively slow; hence, their resultant reactions are related to past pressure occurrences.

Impact

The interpretation of "impact" is further affected based on the differing perspectives on the "state" indicator in the social and natural sciences. Hence, "impact" can be explained as the effect of state change on human society and welfare (social science perspective) or as the physical, chemical, or biological changes to the state of the environment (natural science perspective) (Smith et al., 2014). As a result, from a social science perspective, changes in use and non-use values (such as the loss of goods and services due to biodiversity loss) impact welfare change. The reaction of impact indicators is often delayed because they act in response to changes in environmental state variables. The study focuses on the implications of agricultural land use policies on food security and livelihood. The changes in the ecosystem's structures, functioning, and composition will impact food production and human livelihood in the landscape.

Response

The response component of the framework accounts for human actions taken as a consequence of agricultural policies. It constitutes the driver-based, pressure-based, and state-based response to impacts through various policy measures, such as regulations and information. These interventions or responses can be targeted at any part of the system as identified in the framework. In an optimal process, the responses should affect the driving forces, pressure dynamics, and landscape state, which helps improve the environmental state (Müller et al., 2020). Potentials for response are diverse and dependent on the area of application (environmental, social, and economic), the temporal and spatial context, and the available options and instruments.

Theoretical framework

The theoretical framework underlying the study is socio-ecological systems theory. The social-ecological system theory explains the relationship between humans and their environment in a system and how the decisions of one party affect the other.

Socio-Ecological Systems Theory

The theory highlights humans in nature. As a result, the theory posits that the delineation between social and ecological systems is artificial and arbitrary. Accordingly, the theory proposes that a complex integrated system of relationships between social (human) and ecological (biophysical) subsystems exists, resulting in a two-way feedback relationship (Berkes, 2011). This relationship or feedback can be positive or negative and occurs whenever a people-environment interaction occurs, which varies at different scales of time (temporal) and space (spatial). The system outputs resulting from the interaction are returned to the system as input, either to oppose the initial input (negative feedback) or to enhance it (positive feedback) (Berkes, Folke, & Colding, 2000). Therefore, the subsystems function as joined, interdependent, and co-evolutionary systems.

Hence, the actions of humans affect biophysical systems, while biophysical factors also affect the well-being of humans, and humans, in turn, respond to these factors. According to Berkes (2011), a governance filter serves as the mediating factor between the interaction between the two subsystems (human actions and biophysical processes) (see Figure 1). This governance filter can emanate from institutions, policies, and management measures, all based on ecological knowledge and understanding. This theory is a preferred choice for this study because it allows human-environment interactions to be studied as an integrated whole. This joined human and natural systems study approach exposes new and complex patterns and processes that would otherwise remain concealed when approached separately, either through the social or natural scientists' perspective (Berkes, 2011). Hence, applying this theory gives us the leverage to better understand landscape dynamics (ecology/biophysical dimension) due to agricultural policies (social dimension).

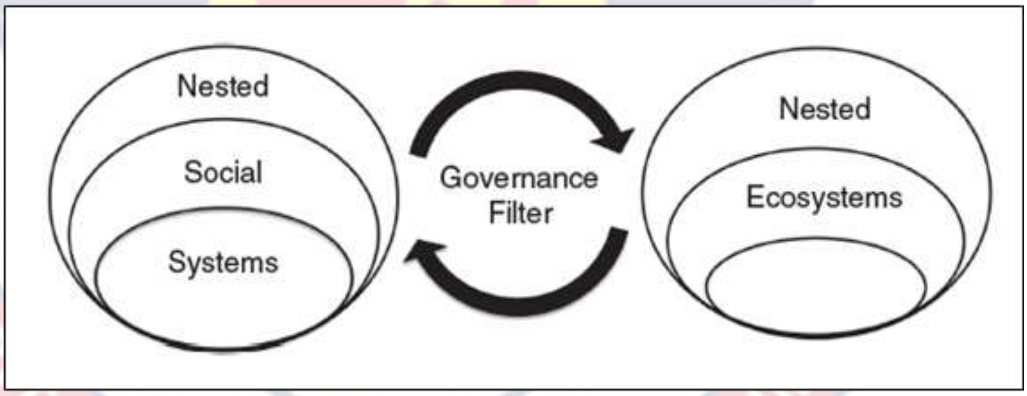


*Figure 2:*Socio-Ecological Theory
Source: Berkes (2011)

Empirical Review

The empirical section of this chapter reviews the literature on the implications of landscape dynamics on food security and human well-being.

***The* implication of landscape dynamics on food security, insecurity, and human well-being**

Landscape dynamics refers to changes in a landscape's physical, biological, and social characteristics over time. These changes can have significant implications for food security and human well-being, as they can affect the availability and accessibility of resources such as land, water, and natural resources, which are essential for growing food and supporting human life. The conversion of natural habitats like forests and grassland into croplands can impact food security. This can lead to the loss of biodiversity and ecosystem services, negatively affecting food production and the sustainability of local livelihoods. According to Anderson, Bayer, and Edwards (2020), climate change can also affect food security, resulting in shifts in temperature and precipitation patterns. These changes can disrupt the food production systems, making it more difficult for individuals to access food for their well-being. Landscape dynamics can also affect social and economic conditions supporting people's livelihoods. Yan, Li, Liu, Li and Zhong (2022) pointed out that adopting a holistic approach to managing landscape dynamics is essential, considering social, economic, and environmental drivers that can affect food security and human well-being.

Further, with a direct impact on food production, landscape changes, specifically changes in land use and availability of resources, affect employment and businesses. These changes in the landscape can affect the ability of individuals and communities to support themselves. It is crucial to consider the implications of landscape dynamics for food security and livelihood and pragmatic steps to mitigate any negative impacts. Mitigation can only occur if the community adopts sustainable land use practices (Burger, Evans, McConnell, & Burger, 2019) and conserves natural habitat. Mitigation could also be achieved by implementing policies, interventions, or programmes to support communities and promote food security.

CHAPTER THREE

METHODOLOGY

Introduction

This chapter focuses on the methodology, starting with the philosophy adopted and the research design guiding the work. It also highlights the study area, which gives a detailed account of the areas studied and the rationale for choosing them. In addition, the chapter also discusses the target population and the technique for deriving an appropriate sample size and technique for sampling. Also, different data collection approaches for LULC categories of the rainforest and socio-economic data are explained in this chapter. The remote sensing image processing, agricultural-land use policies review, socio-economic data analysis methods, and software and statistical tools employed for data processing and analysis were discussed. Finally, the chapter explained the ethical issues considered in conducting the research. It also justifies the approaches, procedures, and methods used in conducting the study.

Philosophical Paradigm

The philosophical foundation of this study is pragmatic research philosophy, combining two research philosophies. The pragmatist does not commit to one system of philosophy and reality but draws liberally from quantitative and qualitative assumptions when engaged in a study. The pragmatist realised there are many ways of interpreting reality when undertaking a study. Hence, no single point of view can better present you with the entire picture of the problem. The pragmatist focuses on combining research approaches to answer the research questions within a single study, thus opening doors to multiple methods, assumptions, and data collection and analysis forms. The research question and objectives of the study compel the researcher to use both a qualitative approach and a quantitative approach to investigate how policies have contributed to landscape dynamics in the RFAZ of Ghana.

The interpretive relates to the qualitative approach in a study where individuals develop the subjective meaning of reality. Reality is subjective, as people's points of view differ from one another. According to Creswell (2013), these subjective meanings are formed through interactions with others and historical and cultural norms in an individual's life. Objective one, which focuses on policies relating to land cover changes in the RFAZ, adopted a qualitative approach whereby land use and spatial planning authorities, agricultural department, and stakeholders were interviewed on the policies implemented accounting for changes in the landscape in the Western Region.

The qualitative approach allows posing questions to elicit answers that quantitative research cannot easily hunt. The quantitative approach was used to tackle the second and third objectives, thus modelling the rate of change in land cover in the RFAZ of Ghana and predicting the future landscape in the study area. This approach is more objective than the qualitative approach. If the study had only been restricted to the quantitative approach, in-depth knowledge would not have been available to explain the causes of land cover in the RFAZ. However, priority was given to the qualitative part of the study; hence, the results were integrated during the quantitative analysis phase.

Research Design

Research design is "a blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings

(Bakker, 2018). According to Sarantakos (2005), research design helps introduce a systematic approach that enables a researcher to assess all study aspects logically. The study employed a mixed-method approach. The mixed method approach combines quantitative and qualitative research techniques, methods, approaches, and concepts into a single study (Johnson & Onwuegbuzie, 2015). The study combined qualitative and quantitative data collection approaches to explain agriculture-land use policies and landscape dynamics in RFAZ. Priority is given to both methodological approaches to effectively cross-validate information on agricultural policies and landscape changes. Using a mixed-method approach overcomes the weakness associated with using only one method.

The quantitative approach was suitable for the study because I quantified the rate of change in a landscape by representing them in frequencies and percentages. Thus, the quantitative research method involved the use of numerical measures. The use of the qualitative approach also helped to provide an in-depth description of agriculture-land use policies in Ghana by focusing on the implication of this on landscape dynamics in the RFAZ. According to Creswell (2016), the qualitative method of analysis is concerned with seeking out the "why" and not the "how" of its topic through the analysis of available data. Thus, the qualitative method enables me to provide an in-depth explanation of the agricultural use policies contributing to landscape dynamics. In line with the mixed method approach, the explanatory sequential design was considered for the entire study. This design comes in two different interactive phases. It starts with collecting and analysing quantitative data, prioritising addressing the research questions. This first phase is then followed by ensuring the collection and analysis of qualitative data.

The study's second phase is designed to follow the results of the first quantitative phase; thus, the researcher interprets how the qualitative results help explain the initial quantitative results (Creswell, 2016). This design was chosen because of its appropriateness in better describing and explaining agricultural-land use policies and their implication on landscape dynamics in RFAZ. The exploratory sequential mixed method design enables the researcher to estimate probable errors that arise by comparing and contrasting quantitative and qualitative results. Data triangulation promotes validity and complements findings, which formed part of the study's relevance. The findings of this study comprehensively explain and provide a clear understanding of why much attention needs to be given to agriculture-land use policies and landscape dynamics in RFAZ in Ghana. Even though the methods under exploratory sequential research design are considered time-consuming, they allow researchers to address all questions relating to 'what,' when ', how', and 'why.' The triangulation of survey data with in-depth interviews and observations was adopted to increase the strength and reduce the weakness of the two philosophical stances behind the chosen research approach.

Study Area

The study area was defined based on location climate, natural vegetation, soil and geology, population, and economic activities (Figure 3).

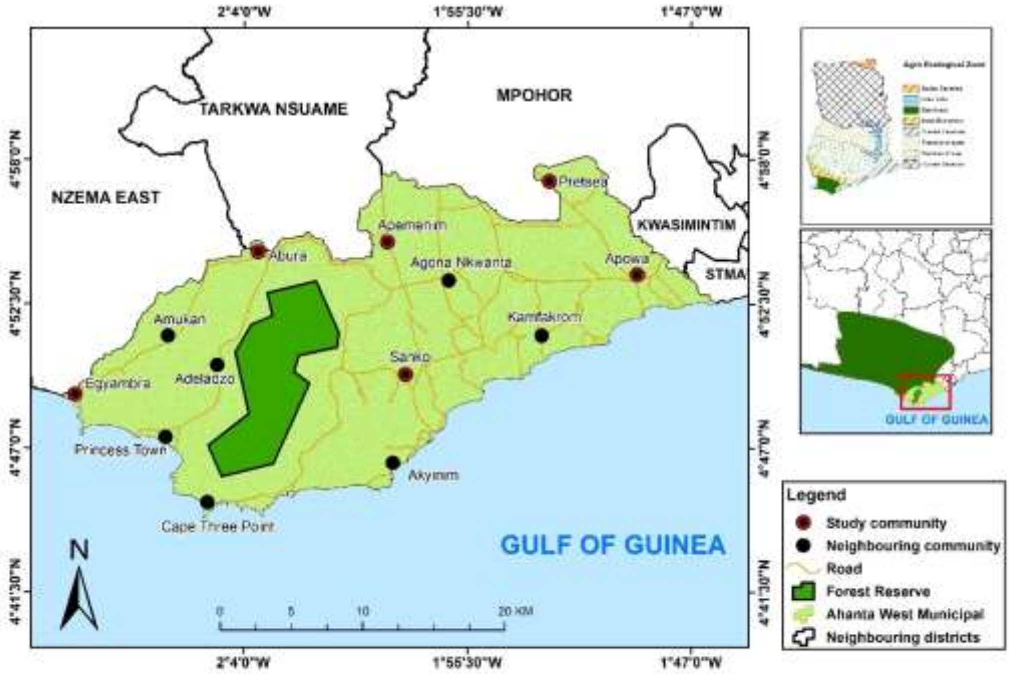


Figure 3: Map of Ahanta West Municipal in the Rain Forest Agroecological Zones of Ghana

Source: Adzigbli (2022)

Location

The study focused on the landscape of Ahanta West district situated in the RFAZ of Ghana in the Western Region between longitude 1º 45' 00" W and 2º 13' 00" W, and latitude 4º 45' 00" N and 4º 57' 00" N with its capital been Agona Nkwanta. The landscape has an estimated area cover of approximately 591 km2 (Ahanta West Municipal Assembly, 2010), approximately 25 Km from the Takoradi business centre. The landscape was bounded to the East by the Sekondi-Takoradi Metropolitan Assembly (STMA), to the West by the Nzema East Municipal Assembly, to the north by Mophor Wassa East district and Tarkwa -Nsuaem Municipal Assemblies, and to the South by the Gulf of Guinea. Some major communities within the

Ahanta West district include Abura, Discove, Egyambra, Agona, Apowa, Apimenim, Preatse, Sankor, and Princess Town.

Climate

The Ahanta West landscape within Ghana's south-western equatorial climatic zone experienced the highest mean temperature of 34ºC between March and April. The lowest mean temperature in the district is 20ºC, recorded in August. The landscape experienced a double maximum rainfall of over 1700mm with very high relative humidity (75% -85%) in the rainy season and low relative humidity (70%-80%) in the dry season (Ahanta West Municipal Assembly,2010). The district experiences the highest rainfall in the country, with an annual mean of 2,200mm and a range of 1,800-2,800mm. The Ahanta West experiences a bimodal distribution of rain, with the major season generally occurring from March to July and the minor season from mid-September to November (UNDP,2007)

Vegetation

The Ahanta West district falls within the RFAZ of Ghana, which is characterised by evergreen forests with very fertile soil beneath (MoFA, 2016; Seini & Nyanteng, 2003). The vegetation cover of the landscape is very dense, dominated by large and thick trees. The Ahanta West Municipality has a diverse vegetation cover due to its location between the coastal savannah and tropical rainforest ecosystems. Grasslands dominate the western part of the municipality, while dense forests with tall trees and shrubs characterise the eastern part. According to Owusu et al. (2019), the vegetation in the Ahanta West Municipality is influenced by the climate, soil type, and human activities such as farming and logging. Tall grasses, shrubs, and scattered trees characterise the coastal savannah in the western part of the municipality. The vegetation in this area is adapted to the dry and hot conditions, with the dominant plant species being Guinea grass (Panicum maximum), Elephant grass (Pennisetum purpureum), and Baobab trees (Adansonia digitata) (Owusu et al., 2019).

In contrast, the tropical rainforest in the eastern part of the municipality is characterised by tall trees that form a dense canopy, with smaller trees and shrubs growing underneath. The vegetation in this area is adapted to the high rainfall and humidity, with the dominant plant species being the African mahogany (Khaya ivorensis), Wawa (Triplochiton scleroxylon), and Black afara (Terminalia ivorensis) (Owusu et al., 2019). Human activities such as farming and logging have led to the destruction of some of the vegetation in the municipality. For example, converting forests to agricultural land has led to the loss of biodiversity and soil degradation. However, efforts are being made to preserve the remaining vegetation and promote sustainable land use practices.

Water bodies

Ahanta West Municipality is a coastal district in the Western Region of Ghana, home to many water bodies essential to the livelihoods and well-being of the people in the area. The landscape has a dendritic drainage pattern. One of the most important water bodies in the municipality is the Pra River, the largest river in the Western Region, used for irrigation, fishing, and transportation (Ghana Statistical Service, 2014). In addition to the Pra River, there are several smaller rivers and streams in Ahanta West, including the Ankobra River, which flows through the town of Axim and is an essential source of drinking water for the community (Miezah & Obeng, 2015). The Aboabo River is another critical water source for the people of Ahanta West, particularly those in the village of Aboabo, who use it for bathing, washing clothes, and fishing (Amankwah et al., 2020). The presence of these water bodies has both positive and negative impacts on the people of Ahanta West. On the one hand, they provide essential resources for livelihoods and food security. On the other hand, they can also pose risks to human health and the environment, particularly when contaminated with pollutants such as plastics, chemicals, and waste.

Soil and geology

The soil dominating the Ahanta West landscape was the Forest Oxysols, which are deeply weathered to over 4m deep (Rhebergen, 2019). This soil type is highly leached with topsoil pH lower than 5.0, thus highly acidic. The acidic nature of this soil makes it highly favourable for plantation crops such as oil palm, coconut, para-rubber, and coffee. The soil is divided according to the colour of the subsoil into Red and Yellow Forest Oxysols at the great soil subgroup level (Adjei-Gyapong &Asiamah, 2002). The landscape is generally flat in topography with few isolated hills ranging in height between 20m to 20m above sea level between Cape Three Point and Princess Akatekyi.

Population

The Ahanta West district has a total population of 105,984, with 50.4% female and 49.6% male (Ghana Statistical Service, 2022). The district has an average population density of 161 people per square kilometre. Rural communities largely dominate the landscape, with about 66.8% depending on the natural environment and ecosystem for food and livelihood (Ahanta West Municipal Assembly, 2018).

Economic activities

The landscape is rural-dominated, with most of the population engaged in farming activities (Ghana Statistical Service, 2014). Most of the local communities in the landscape have recently cultivated several hectares of cash crops such as cocoa oil palm, rubber, and coconut plantations. The peculiar characteristics of Ahanta-West have made the landscape a central hub for the majority of cash crops, principal industrial crop cultivation in the country, and other major food crops. The landscape also supports various cereals and vegetables, with rice, maize, cassava, plantain, banana, cocoyam, okra, pepper, and garden eggs being 'prominent (Ghana Statistical Service, 2014). In addition to agriculture, the municipality also has a thriving fishing industry, a significant income source for many households in the area (Ghana Statistical Service, 2014). The production of salt is another important economic activity, with many communities engaged in the harvesting and processing salt from the sea (Ministry of Local Government and Rural Development, 2019).

Moreover, the municipality has a nascent tourism industry, with attractions such as the Cape Three Point Forest Reserve (Ministry of Local Government and Rural Development, 2019). The reserve contains several hiking trails, waterfalls, and beaches, which allow visitors to experience the area's natural beauty and cultural heritage (Ghana Wildlife Division, n.d.). The tourism industry has the potential to provide employment opportunities and generate income for the local economy. The recent discovery of oil within the landscape at Cape Three Point has led to the emergence of several oil drilling companies in the district.

Target population

A population can be viewed as all groups of people or items with a similar characteristic of interest to a study. A target population for a research study refers to the entire group of individuals or entities to which the researcher would like to generalise the findings (Creswell, 2014). The target population for this study constitutes cash crop (specifically rubber and oil palm) farmers under ROPP and NSSP who have farmed for at least ten years and miscellaneous bodies who can respond to questions relating to issues on agricultural land use policies. The Ghana Rubber Estates Limited (GREL) and Norpalm Oil Company were involved in the study because these institutions were the implementers of ROPP and NSSP, a significant agricultural intervention in the RFAZ. The study also engaged reps of cash crop farmers groups from each community.

Sample Size

The study targeted cash crop farmers under ROPP and NSSP who have farmed in the landscape for not less than ten years. This group of people with similar characteristics can be categorised as an infinite population. The study used a sample size of 192, which was obtained using the infinite sample size formula (Duku et al., 2022; Kafando et al., 2013; Mensah et al., 2013; Olesia et al., 2015). In all, a long-serving representative of the selected key stakeholder institutions and miscellaneous bodies participated in the in-depth interview. Finally, the study recruited six (6) stakeholders: MOFA (1), GREL (1) and Norpalm (1), Forestry Commission (1), and the District Assembly (2) and one head of cash crop farmers group each from the selected communities for unstructured in-depth interviews. These stakeholders were selected based on their prior knowledge of issues relating to landscape changes for at least fifteen (15) years. The stakeholders worked closely with cash crop farmers in the study area and had a high level of understanding of various agricultural land use policies.

Sample Procedure

In this study, since all the elements in the target population cannot be questioned, Creswell (2013) pointed out that a sampling procedure should be adopted to reproduce the characteristics of the entire population for the study. In terms of sampling procedures, both probability and non-probability sampling were used in the study. The probability method used in the study was multistage. The multistage sampling technique combines two or more probability techniques to select respondents for a study. It is used when the population elements are spread over a vast geographical region, and it is impossible to obtain a representative sample with only one technique (Alvi, 2016). Thus, the final unit or element of a population used in an investigation is obtained after sampling at several stages.

In this study, the clustering sampling method was the first sampling procedure. The landscape was divided into three (Eastern, Central, and Western) clusters. This approach aimed to capture all cash crops (rubber and oil palm) farmers across the landscape who were beneficiaries of either ROPP or NSSP. Thus, from each cluster, two communities were selected based on the acreage of rubber and oil palm plantation cover. Finally, simple random was used to sample cash crop farmers from six communities. The selected communities were Abura, Egyambra, Apimenim, Sankor, Apowa, and Pretsea. These communities are selected because they depend heavily on rubber and oil palm cultivation in the RFAZ (Adeho, 2015; Lisa & Roble, 2012). For instance, Abura, Egyambra, and Apimenim farmers mainly engaged in rubber plantation, while Sankor, Apowa, and Pretsea were predominantly into oil palm farming. The data collection exercise used Kobo Toolbox, an electronic medium that aids data collection. It is used on mobile devices and works both on and offline. This medium was adopted since Kobo Toolbox has all data readily available for cleaning and analysis.

The non-probability sampling procedure used in the study was expert purposive sampling. This method was adopted to select the study's six (6) key informants from miscellaneous bodies and six (6) cash farmers' group reps. The following criteria guided the selection: the ability to understand various agricultural-land use policies and prior knowledge of landscape changes for at least fifteen (15) years. This was conducted with key informants in the study area, such as reps from the Ministry of Agriculture, Land Use and Spatial Planning Authority (LUSPA), Forestry Commission Ghana, Rubber Estates Limited (GREL), and Norpalm Company Limited. Participants for the interviews were contacted for an appointment where they were briefed on the purpose of the study. After the successful booking of the appointments, permission was sorted before recording the conversation on the day of the in-depth interview. The interviews lasted from 45 minutes to 1 hour.

Pilot study

A pilot study was done before conducting the interview section for the study. The pilot study was to determine the appropriate questions to ask cash farmers on agricultural land use policies and their implications on landscape dynamics. The pilot study determines the suitability of questions and instruments, comprehensiveness of questions, and respondents' understanding of the questions. Thus, it helps to check the reliability and validity of the structured instrument. The pilot study was done at Amenful Kuma and Adelekazo communities a month before data collection. After the pilot study, final comments from the cash crop farmers were acknowledged and incorporated into the final drafted structured interview guide. The lesson learned from the pilot study helped the researcher to know how to approach the cash crop farmers.

Training of field Assistants

Three (3) research enumerators were appointed and trained in the data collection process. The rationale for the three enumerators was to help administer the computer-assisted Personal Interviews within one week. Some enumerators recorded ground truth points of varying features using a GPS device. The following criteria guided the recruitment of the enumerators: the ability to write, speak, and interpret Nzema and the English language; the level of education (specifically secondary and tertiary will be considered); and prior knowledge of issues relating to landscape dynamics. The field assistants underwent three days of intensive training to help them understand the nature of the study. It was also used to enrich their knowledge and skills in data collection procedures for the study.

Data Collection instrument

This section highlights the data collection instruments used in the data collection exercise. The instruments include in-depth interviews and structured interviews. The in-depth interviews hinted at the qualitative data, while structured interviews focused on the quantitative data collection.

In-depth interview guide

An interview guide was designed to conduct an interview section with the following stakeholder institutions: Agriculture Extension officers of the Ministry of Food and Agriculture (MoFA), Ghana Rubber Estates Limited (GREL), Norpalm, Forestry Commission, and the District Assembly. The interview guide was designed to touch on issues concerning agricultural land use policies and drivers contributing to landscape changes. It also includes the implication of landscape dynamics on food security or insecurity and institutional arrangements for the planning and managing of the RFAZ. The landscape was the major area of discussion during the interview section. The study also engaged some farmers in the in-depth interview.

Structured interview

The structured interview was in the form of computer-assisted personal interviews. This comprised five sections (A, B, C, D). The introductory section (Part A) of the instrument consisted of the consent form information and the geographic coordinates of the respondents. Part B entailed the demographic characteristics of respondents focused on gender, age, religious affiliation, educational level, marital status, income, type of cash crop cultivated, years of experience in cash crop farming, farm ownership, and farm management. Part C captured issues relating to the rate of change in the RFAZ land cover. The section also rated the acceptability of landscape changes (status of the landscape) and the rate of increase and decrease in land cover on three scales (low, moderate, and high). It also rated how issues of land cover change were discussed with local authorities from very low to very high. Part D consisted of Likert scale questions (0–5) measuring the pillars of landscape (Production, conservation, and livelihood) from very poor to very high. Through in-depth interviews and a review of literature, a total of (27) questionnaire items were constructed capturing the three pillars of landscape about agricultural-land use policy dimension: The production pillar (nine items), the conservation pillar (four items), and the livelihood pillar (twelve items).

The computer-assisted personal interview had both open-ended and closed or forced choice-format questions. In the open-ended question, the respondents formulated their answers. Respondents were forced to choose between several options in the closed formats. The open-ended format allowed for examining various possible themes arising from an issue. The instrument was distributed to the respondents (cash crop farmers) in their respective houses by the researcher and trained enumerators to collect the quantitative data.

Data collection procedure

During the pilot study, an initial visit was made to request permission from the opinion leaders and win the farmers' trust and confidence. It also helped the researcher observe the landscape's physical landscape and various ecological aspects in the study area. An introductory letter from the Department of Geography and Regional Planning was sent to the selected communities and miscellaneous bodies sampled for the study. The introductory letter permitted the researcher to visit the study area and solicit information from the cash crop farmers. The pilot study's results helped the researcher design an appropriate structured interview instrument and in-depth interview guide for data collection. The data collection was in two sections specified under the research design.

The first phase involved in-depth interviews with cash crop farmer cooperative heads and key informants from the stakeholder institution: the Director of the Agriculture department in Ahanta West district, Agriculture Extension officers of the Ministry of Food and Agriculture (MoFA), Ghana Rubber Estates Limited (GREL), and Norpalm oil company, Forestry Commission, the District Assembly. The interview for these participants lasted 90 to 120 minutes and was held in their offices. The reason for the interview was to know the implications of agricultural use policy on landscape dynamics in the Rainforest Agro-ecological Zone. The in-depth interviews with cash crop farmers took place in a place comfortable for them. The second phase of the data collection focused on the modelling of the landscape, which involved geospatial data. The geospatial data was collected through the USGS database, where Landsat satellite imagery with 30m resolutions was downloaded.

Data and Source

Data were obtained from both primary and secondary sources of information. The multiple data sources support a more conclusive and accurate conclusion, unlike when a single data source is used in a study (Yin, 2003). Primary data were collected using a structured interview and in-depth interviews for cash crop farmers as well as stakeholder institutions and miscellaneous bodies such as the Ministry of Food and Agriculture (MOFA), Ghana Rubber Estates Limited (GREL) and Norpalm, Forestry Commission, and the District Assembly. Information from the secondary sources was obtained from the United States Geological Survey (USGS), existing documents such as books, articles, journals, surveys, and other studies on agriculture-land use policies and their implication on landscape dynamics. The study's primary form of documentary data includes existing agriculture-land use policies from the Fourth Republic (after the 1992 constitution). These policies were the Rubber Outgrower Plantation Project (1994), Norpalm Smallholder Scheme Project (1996), Ghana Environmental Policy (1995), and Ghana National Spatial Development Framework (2015). Secondary data was essential to understand the rationale of supporting evidence regarding past situations and trends and the constraints in the development efforts of policy, rules, and regulations regarding landscape dynamics.

Geospatial data acquisition

Satellite image data acquisition

Landsat satellite images of RFAZ from 1991 to 2022 were downloaded from the United States Geological Survey's website (http://earthexplorer.usgs.gov/). The images were in three segments: image data of two different scenes for 1991, 2007, and 2022 (Table 1). These years were selected because various policies were implemented within these years. The availability of the images influenced the selection of the satellite images, the amount of cloud and scene cover, and the overall quality of the images, which was very close to the best (https://lta.cr.usgs.gov/DD/landsat_dictionary.html). The selected images help to assess the land cover of the Rain Forest Agro-ecological Zone from 1991 to the present. The table below shows the satellite image properties for the RFAZ.

Table 1:Description of downloaded Landsat Satellite data

Sensor platform	Year of Acquisition	Path/Row	Spatial resolution (m)
Landsat-4 TM	1991-01-01	194/057	30
Landsat7 ETM	2008-02-01	194/057	30
Landsat-8OLI_TIRS	2022-03-03	194/057	30

Source: United States Geological Survey (USGS)

Data Processing and Analysis

Agricultural Policy Analysis Approach

Policy analysis synthesises information, including research results, to produce a format for policy decisions and determine future policy needs and relevant information (Patton, Sawicki & Clark, 2015). The study adopted the six steps of policy analysis processes highlighted by Patton, Sawicki, and Clark (2015). These steps include problem definition, determination of evaluation criteria, identification of alternative, evaluation of alternative, comparison of alternatives, and assessments of outcomes. The study's problem relates to converting ecological and arable lands to cash crop production, which could affect ecological integrity and food security. I reviewed both private and government policies on agriculture and land use changes of the RFAZ. The conceptualization of policies in this study refers to agriculture projects and programs implemented by government and private cash crop production companies in the RFAZ. Based on the literature, I created a list of potential policies and policy documents relating to those projects and programs.

The alternative policies were evaluated based on production, conservation, and livelihood criteria. The evaluation criteria are also relevant to the policy for land use planning. The policy adopted a descriptive policy approach involving both qualitative and quantitative information. The quantitative information was dealt with using a comparative matrix, while qualitative analysis relied on in-depth interviews. These documents were categorized into three broad policy categories: agriculture, environment, and spatial development. In identifying alternative policies, the study purposely selected four (4) policies that comprise two agricultural interventions/programs, namely Rubber Outgrower Plantation Projects (ROPP) and Norpalm Smallholder Scheme Project (NSSP). The ROPP and NSSP were selected because the policies employ about 80% of rural communities in the RFAZ (Adeho, 2015; Lisa & Roble, 2012), which focuses on income generation among smallholder farmers.

Even though these policies aim to increase rural income, they also significantly affect the landscape's ecology. The other two policies, the Ghana Environmental Policy (GEP) and Ghana National Spatial Development Framework (GNSDF), focused on the entire landscape planning, whose contributions are vital in sustainable land use management. The policy analysis approach employed content analysis to explain the relations between landscape dynamics and policies in consonant with results from the land cover transitions analysis in the RFAZ. The content analysis approach synthesizes various agriculture and spatial development policies, their implementation plans between 1991 to 2008 and 2008 to 2022, and their goals and objectives. The summary of the policies reviewed in the study area is indicated in Table 4

Table 2: Agricultural-land use policies/programs implemented

Policies/programs	Policies duration	Policy goals and objectives
Rubber Outgrower Plantation Project (ROPP)	1992- 2021	Increase cultivation and rehabilitation of rubber farms in rural communities. It also targets poverty alleviation.
Norpalm Smallholder Scheme Project (NSSP)	1994-2021	Improve the productivity of agricultural production.
Ghana Environmental Policy	1995-present	It seeks to protect and conserve natural resources.
Ghana National Spatial Development Framework (GNSDF)	2015- 2035	Rules and Regulations on the use, management, and development of infrastructures on the landscape

Source: Adzigbli (2022)

In assessing the alternative policies, the study employed binary logistic regression to explore the impact of ROPP and NSSP on landscape change. The impact of agricultural policies was displayed through the spatial map in the study area, and finally, before and after, a comparison was made concerning agricultural land use policies and landscape changes.

Geospatial Data Processing and Analysis

Ground truthing and training sample digitizing

To model the spatial and temporal changes of the major LULC categories of RFAZ, GCPs of various LULC types for each year were recorded using the GPS device in a participatory mapping approach. Some GCPs were used as training samples for LULC classification, while others were used in the classified images' cross-validation (accuracy assessment). Again, personal observation of the physical and built environment of RFAZ was also conducted. During the mapping exercise, some key farmers who have lived in the selected communities for not less than ten years and have in-depth knowledge about the changes in the physical landscape were selected for the exercise. In addition, coordinates of LULC categories that were difficult to access on the field were recorded from Google Earth imagery using the on-screen digitization method (Madarasinghe et al., 2020).

Accuracy Assessment

The classified images were validated by calculating and analyzing the overall Kappa and accuracy using the formulas provided by Jenness and Wynne (2005). Two hundred and sixty (260) of the GCPs were randomly sampled each year and used for the accuracy assessment of the classified images. The accuracy or agreement is the probability (%) that the classifier has labelled an image pixel into the ground truth class. It is the probability of correctly classifying a reference pixel (Yan et al., 2006). The kappa statistics is generally accepted as a measure of classification accuracy for both classification models (Jenness & Wynne, 2005). Kappa values are characterized as less than 0 as indicative of no agreements and from 0 to 0.2 as slight, 0.2 to 0.41 as fair, 0.41 to 0.60 as moderate, 0.60 to 0.80 as substantial, and finally, from 0.81 to 1.0 as almost perfect agreement (Appiah et al., 2015). The overall accuracy of a thematic map is the total classification accuracy. The accuracies of the classified images for 1992, 2007, and 2022 met the LULC categorization accuracy of 85% (Thomlinson et al., 1999). The Kappa statistic also represents a substantial agreement between the predicted and observed.

Satellite image processing, classification, and analysis

The vital calibration approach is image pre-processing, which allows correcting recorded pixel values and establishing a substantial link between the acquired image data and the biophysical process. Image pre-processing was first carried out after acquiring all the images for this study. All the Landsat satellite images for the three-segment years were first projected into the Ghana Meter Grid Coordinate System. This was meant to ensure consistency and accurate assessment of the landscape. The Landsat-7 ETM, which had scanlines, was corrected with the Landsat gap fill, an extension tool in Environment for Visualizing Images (ENVI) version 5.3 software. Atmospheric correction was performed on the imageries using *ENVI* version *5*.3. The Landsat scenes in each segment year were mosaic, and the study area was subsets *from* the mosaic scenes.

A Support Vector Machine-supervised classification was applied to the pre-processed images (Cláudia et al. 2019). In addition, various band combinations were carried out, as well as visual interpretation using shape and texture. This initial analysis, together with the GCPs from the field and on-screen digitization, helped to arrive at the final signature file of eight (8) major LULC categories: wetland, water bodies, shrubland, forest, oil palm plantation, built-up (including all kinds of building and concrete surfaces), croplands and rubber plantation. The LULC were developed based on expe*r*t knowledge from the study area. According to Saha et al. (2005), expe*r*t understanding of the landscape accurately represented the phenomenon under study. The LULC class statistics were generated in ArcGIS Pro 2.8 in hectares. The percentage of each LULC category was then calculated in

Microsoft Excel version 16 by dividing the area of each LULC category by the total land area, which is then multiplied by a hundred (100). Table 3 presents a description of LULC categories in the study area.

Table 3: LULC Categories and their Description

LULU Categories	Description
Wetland	Wetland and mangroves
Water bodies	Rivers
Shrublands	Woody vegetation, including both open areas, bushes, and fallow lands
Forest	Cape Three-point Forest reverse
Oil Palm	Oil palm farms (smallholder and large scale -plantations as well as coconuts.
Built-up	Residential, industrial, and rural communities. It includes all kinds of buildings and concrete surfaces, such as roads.
Croplands	Annual and biannual food crop farms.
Rubber	Establishes plantations and out-grower smallholder plantations

Source: Adzigbli (2022)

Change Detection

The change detection was conducted to assess areas that have transformed the RFAZ landscape between 1991-2022. According to Lu et al. (2004), LULC assessments focus on finding the proportion, rate, spatial distribution of change and the transition of land cover categories. The post-classification change detection technique was adopted to compare individual independent classified maps for 1991, 2008, and 2022 (Dalle et al., 2011). This technique is the most efficient technique used in monitoring land cover changes. Thus, the technique can minimize atmospheric and sensor disturbances and environmental effects on the output. The change detection enables the study to generate the transition matrix (Tewkesbury et al.,2015). The land cover matrix comprises independent sizes of the Rainforest Agro-ecological land cover units in the initial year and the conversion until the year's end. The values in the diagonal of the transition matrix represent persistent land cover areas per land cover categories, whereas the off-diagonals are the transitions in the land cover type from 1991-2008 and 2008-2022.

The matrix includes gross losses, gross gains, and net changes to understand the dynamics in the RFAZ landscape (Pontius et al., 2013). The gross loss is the sum of all proportions per individual land cover categories in the previous years that have changed to other LULC categories in the current year (1991-2008 and 2008-2022). The gross losses are calculated by subtracting the persistence from the total in the right-hand column (Pontius et al., 2013). The gross gains are the sum of all proportional LULC categories that have been converted from the previous to the current years (1991-2008 and 2008-2022), and they have been deduced by subtracting the total column from the persistence values. The net change is the difference between the gross gains and losses. The annual rate of change was calculated for all the LULC categories in the RFAZ using the compound interest law and mean annual rate of change formula as indicated in Puyravaud (2003). The A_1 and A_2 the formula denotes the areas of land cover categories in the present and previous year. The t_1 and t_2 represent the time of LULC change in present and previous years, while R indicates the total annual rate of change, respectively.

$$R = \left(\frac{1}{(t_2 - t_1)}\right) ln\, ln \left(\frac{A_2}{A_1}\right)$$

Intensity Analysis

The combined function tool in the ArcGIS 10.8 software was used to identify the changes in major LULC categories. This contributed to the construction of the transition matrix. The quantities from the transition matrix served as input data for the intensity analysis conducted at three levels: interval, category, and transition (Akinyemi et al., 2017; Ekumah et al., 2020; Niya et al., 2019).

Spatial Variables in Modelling of the Landscape

The RFAZ landscape was modelled and predicted for ten years using ArcGIS Pro 2.8 and QGIS 2.8.1 software. Statistically, the relationship between the landscape dynamics and independent variables (anthropogenic factors) was investigated in the study. The anthropogenic factors used in the model were the distance from the road, distance from the settlement, distance from the rubber processing plant, distance from the Norplam oil processing plant, farm sizes, distance from the market, farming population, and community population. The selection of anthropogenic factors was influenced by studies on driving forces of LULC changes in the RFAZ (Kankam, Osman, Inkoom & Fürst 2022). Anthropogenic factors accounted for about 80% of land cover changes in the RFAZ (Loh, Asubonteng, &Adanu, 2022). These variables were used in this study because of their spatial measurability. The dependent variables were transition to rubber, oil palm, and built-up. The aim was to associate major LULC changes with their determining anthropogenic factors in the Landscape. Distance from the road, distance from the settlement, distance from the rubber processing plant, distance from the Norpalm oil processing plant, and distance from farms were based on the Euclidean distance model in the ArcGIS Pro 2.8. At the same time, the cash crop farming and community populations were mapped spatially and interpolated using the average interpolation method. The maximum Variance Inflation Factor (VIF) cut of >7.5 was used to assess the multicollinearity of the anthropogenic factors of the land cover changes. Explanatory regression was performed to identify the prominent variables (anthropogenic factors) that were statistically significant to predict the model in the landscape.

Model Validation

The predicted and simulated maps for 2032 were validated using the classified LULC maps of 2022 as the reference. The validation method used to train the model was artificial neural networks, which produced the Kappa Statistics of 0.84 (Figure 13), indicating a good consistency between the predicted result and the actual LULC. A Kappa coefficient value 1.0 indicates a perfect between the reference and simulated map of the RFAZ. The predicted, simulated, and changed maps were developed for the RFAZ landscape 2032.

Simulation for Rain Forest Agro-ecological landscape

The Markov Chain and Cellular Automata analysis (CA-Markov) model predicted LULC change in the RFAZ. CA-Markov models combined a Markov algorithm to simulate the number of changes and the Cellular Automata (CA) algorithm to simulate the change allocation (Zare, Panagopoulos, & Loures, 2017). Cellular Automata (CA) employs the proximity concept to show that regions closer to the existing areas of the same class are more likely to change to a different class. The transition probability matrix determines the likelihood that a cell or pixel will move from a land use category or class to every other category (Singh et al., 2015). Land use and land cover simulations for the study areas were conducted using Molusce in Quantum GIS software. The purpose of the simulation was to predict the expansion of rubber and oil palm and built-up, thus the transition of other LULC classes to rubber, oil palm, and built-up. Transition probability matrices were computed for 2022 (using LULC maps of 1991 and 2007) and 2032 (using LULC for 2022 and 2032). The transition probability matrix shows areas likely to be transitioned to other classes. Using the transition probability matrix and the transition potential model, the 2032 maps were developed. The Kappa Components were used to validate the predicted maps for 2032, with 2022 LULC maps serving as the reference. After the validation process, the predicted maps for 2032 were generated.

LULC Scenario for Predicting Rain Forest Agro-ecological landscape

Based on local agricultural policies and socio-economic drivers, in the RFAZ from 1991 to 2022, three future scenarios have been defined to predict land cover for 2032 using the Markov model. No existence of agricultural policies characterizes the first scenario to influence the landscape with the trend in LULC change from 1991 to 2022 and will not change greatly from 2022 to 2032. The second scenario is characterized by the operationalization of agricultural policies in the landscape, in which we assume that the existence of agricultural policies helps to transform LULC quickly by considering the crop production level, high demand for cash crops (rubber and oil palm) market and growth rate of population, urbanization level, and high demand for land for cash crop farming in 2032. The third scenario is characterized by ecological and cropland protection. In this scenario, wetlands, water bodies, and forest reserves are designated as nature reserves that play an important role in ecological security and cannot change to other land use categories. The basic cropland is then taken as a restricted area where the croplands cannot be converted into other land cover types.

Socio-economic survey data processing and analysis

The qualitative data were analyzed with the aid of the MAXQDA Pro. Whereas Stata SE version 14.2 (StataCorp, College Station, TX, USA) and Statistical Package for Service Solution (SPSS) version 26 were used for the quantitative data from the respondents.

Socio-economic survey data analysis

The descriptive statistics were performed using frequencies and percentages to understand the distribution of socio-economic variables in the study. Cross-tabulation was used to analyse the bivariate relationship between landscape change, demographic background, and the impact of ROPP and NSPP. Further, binary logistic regression analysis was adopted to analyse the effect of both ROPP and NSSP on landscape changes in the RFAZ.

Measures

The socioeconomic data gathered through structured interview administration were edited, coded, and reduced. The socio-demographic variables in the study were coded as: gender (male=1, female=2); age (young adult: <35 years, middle-aged adult: 35-55 years and old-aged adult: >55 years; (Duku et al., 2022); religion (Christian =1, Islamic =2, Traditional =3 and Other =4); education level (No formal education=1, Basic =2, Secondary =3 and Tertiary =4); marital status (Single= 1, Married= 2, Divorce/separated

= 3 and Widowed); type of cash crop cultivated (rubber = 1and oil palm =2); farm ownership (rented = 1, family = 2, friends = 3, private = 4, government = 5, and self = 6); farm management (self =1, husband =2, wife =3, children =4 and non-family member = 5). The percentile was used to group years of farming experience into low experience (10-14 years), moderate experience (15- 18 years), and high experience (19- 36 years). Using the percentiles, income was grouped into low income (920GH₵-7360GH₵), middle income (7361GH₵-15600GH₵), and high income (15601GH₵ - 35100GH₵).

Outcome variable

The dependent variables used in the study were landscape change. The landscape change variable was rated on a 3-point Likert scale to reflect the level of change starting from 1=low, 2=moderate, and 3=high. However, 1 - 2 = No change while 2= change. The reliability of the data yields a Cronbach's alpha of 0.742, indicating moderate reliability.

Covariate

The explanatory variables used in the model were summarized in Table 4, aimed at understanding the state of agriculture systems, biodiversity conservation, and livelihoods. Based on the literature, these indicators were reviewed and used in the model (Kankam, Osman, Inkoom, & Fürst, 2022; Han, Yang, & Song, 2015). Each question on the impact of the policies (ROPP and NSSP) was rated on a 5-point Likert scale to reflect the level of change starting from 1=low, 2=moderate, to 3=high. To conduct a principal component analysis, the indicators were recorded in 0 and 1, indicating "no impact" and "impact" of the policies (ROPP and NSSP), respectively. The principal component analysis was used to extract 18 out of 25 variables under

ROPP and 15 out of 25 under NSSP from the questionnaire, respectively (Table 4). A Cronbach Coefficient (a) was used to check the internal consistency of the measured variables. All the variables measuring landscape status (agriculture systems, biodiversity conservation, and livelihoods) under ROPP demonstrated a good internal consistency measure with a Cronbach Coefficient (a) of 0.752 for agriculture systems pillar a=0.966 for biodiversity conservation and a=0.761 for livelihoods. Regarding NSSP, the Cronbach Coefficient (a) for agriculture systems, biodiversity conservation, and livelihoods were 0.820, 0.514, and 0.664, respectively.

A composite indicator was created for both ROPP and NSSP using principal component analysis to analyze the impact of agricultural policies on landscape status. These variables covered different aspects of landscape status (agricultural systems, conservation, and livelihood) of the DPSIR frameworks, as indicated in Figure 1. The principal component analysis is a statistical methodology for reducing the data's dimensionality while keeping the original data's accuracy (Campbell et al., 2001; Pett, Lackey, & Sullivan, 2003). Thus, it reduces many variables to fewer factors while still explaining most of the variance of the original data. Again, all the factor loadings were all positive and above 0.1.

Table 4: Indicators for measuring agriculture policy impact

Agriculture Policy impact	ROPP	NSSP
	Factor loadings	
Benefit outcome	**0.59**	**0.82**
	48.56	**439.64**
I have cultivated more crops than in previous years.	0.763	0.877
The policy has made me change my farming pattern	0.57	0.80
I have acquired training in modernized agriculture technology	0.66	0.90
The policy has changed my farm size	0.501	0.87
Agriculture Input	**0.53**	**0.64**
	29.15	**194.44**
I have applied the right proportion of fertilizer	0.74	0.29
The policy enables me to apply the right proportion of pesticides	0.48	0.86
I have acquired higher-yielding seedling breeds	0.78	0.79
The policy has helped me get access to credit.		0.840
conservation	**0.65**	**0.51**
	253.61	**13.35**
The policy helps to manage forests and other natural resources	0.80	0.76
The policy helps to provide ecosystem services in the landscape	0.86	0.76
The policy helps to improve biodiversity	0.92	
Infrastructure		
New roads have been constructed and rehabilitated	0.75	0.74
New schools have been constructed in this community	0.77	0.74
New hospital facilities have been constructed and renovated	0.67	
Water and sanitation have been improving in this community	0.54	
		0.66
Livelihood		**233.86**
The policy has increased my livelihood	0.74	0.90
The policy has improved my wellbeing	0.59	0.89
The policy has improved my monthly income	0.22	0.76

Source: Adzigbli (2022)

Data management

The study employed the institutional policy and guidelines by the University of Cape Coast about handling data from the field. After each day's interviews, the recorded interviews, as well as field notes and pictures, were kept confidential on a personal laptop that is password protected. The recorded interviews, observation notes, and transcripts will be stored safely to prevent a third party from accessing them. After transcription, the audio source file will be deleted, and the transcripts will be password-protected. Photos and participant meanings will be kept on a password-protected external hard drive and the source file immediately. Responses from questionnaires have undergone cleaning to remove incorrect, corrupted, incorrectly formatted, duplicate, or incomplete data within the dataset. Quality assurance approaches were employed to ensure the collection of valid and reliable transcribed data, and responses from questionnaires were kept by the Principal Investigator for data management, and the source file from field assistants will be discarded. Access to data was granted to research assistants. The data was kept for two years. The duration will give the researcher ample time to develop research papers alongside the main thesis. After two years, the data would be cleared. Since the data is stored on the encrypted cloud and storage devices, the data would be permanently cleared by completely formatting the devices.

Limitation

One of the challenges in the field was a refusal to participate in the research and limited data collection days. Again, the population of rubber and oil palm beneficiaries was unknown.

Ethical Issues

This study ensures that the highest ethical standards are maintained throughout the study. The first step was to get ethical clearance and permission from the Institutional Review Board, University of Cape Coast. During the data collection, the research teams obtained informed consent from the participants after explaining the purpose of the study and their roles. Participation in the study was voluntary, and there was no coercion. The study participants were informed that they could withdraw from the study at any time, which has not affected them. Confidentiality and privacy were maintained at all levels of the research process, and the research participants were individually identified in the data analysis.

There was no monetary compensation from the study. However, the study anticipates that the RFAZ, where the study was conducted, would be the first beneficiary since it is studying landscape dynamics concerning agricultural land use policies. The policymakers, community, and planners benefit from the research as critical issues relating to landscape dynamics in RFAZ. In the era of COVID-19, the necessary protocols of physical distancing, nose masks, and hand sanitizers were adopted during the field data collection. This study is for academic purposes and demands quality in the processes. As such, the researcher carried letters that would introduce him and elucidate the importance of the research. Informed consent and voluntary participation were signed, and all respondents were assured confidentiality. Data supplied by respondents was treated with care and confidentiality. To avoid any issues of argument regarding plagiarism, the current researcher cited all sources of information, plates, and figures that aid in the discussion and the entire study.

CHAPTER FOUR

THE APPLICATION OF AGRICULTURAL LAND USE POLICIES IN THE RFAZ

Introduction

This study chapter analyses the application of agricultural land use policies in the RFAZ. The chapter also highlights the impact of ROPP and NSSP on landscape change.

Assessment of agricultural-land use policies in the Rainforest Rain Forest Agro-ecological Zone of Ghana

The agricultural-land use policies in RFAZ address the issue of landscape dynamics about landscape state (production, conservation, and livelihoods). According to Scherr et al. (2014), a sustainable socio-ecological landscape represents a stool centred on three pillars. The landscape pillars refer to the indicators that measure the state of the landscape over time. These pillars include Production, conservation and livelihood, and institutional policies (Table 5).

Table 5: Comparing landscape pillars in the Rain Forest Agro-ecological Zone

Landscape Pillars	Landscape elements	Agricultural-land use policies			
		ROPP	NSSP	GEP	GNSDF
Production	Sustainable Production	✔	✔	✔*	□
	Land management	✔*	□	✔*	✔
	Production systems	✔	✔	✔*	□
	Biodiversity	□	✔	✔*	□
Conservation	Natural resource management	□	✔*	✔*	✔
	Ecosystem services	□	✔A	✔*	□
Livelihood	wellbeing	✔	✔	✔*	✔
	Infrastructure	✔*A	✔*A	✔*	✔
	Human settlement	□	□	✔*	✔

✔= The policy considered landscape elements extensively. □= Landscape element is not considered in the policy. 'A' indicates the adverse impact of the policy on the landscape. * denotes that the policy is relevant for land use planning.
Source: Adzigbli (2022)

Landscape Pillar of Production

Production deals with landscapes that maintain sustainable production systems. The production landscape pillar included the physical process of planting tree crops. It considers land management in terms of access to land and other agricultural inputs that influence production. The landscape pillar on production also considers production systems used in cultivating cash crops in the RFAZ, which influence production on the landscape. The key production elements in Table 5 include sustainable production, land management, and production systems.

Element of Sustainable Production

The production element, an indicator for sustainable agriculture in the RFAZ, teases out key production strategies adopted to evaluate sustainable cash crop production in ROPP, NSSP, GEP, and GNSDF.

With the production pillar of the RFAZ landscape, ROPP mainly focused on producing large-scale rubber plantations to feed the rubber processing industries. The ROPP has allowed smallholder farmers to benefit from agricultural inputs such as rubber seeds and planting materials to accelerate rubber production. An in-depth interview

a rubber farmer in the Abura community said *the increased rubber production in this landscape has expanded compared to 30 years ago. The ROPP has helped the farmers plant more rubber in this community*. The promotion of cash crops through the Ministry of Food and Agriculture has prompted smallholder farmers to cultivate rubber plantations. Thus, the landscape is extensively utilized for rubber plantation, and the activities have been sustained over decades. The direct effects on productivity can be attributed to the profitability margin smallholder farmers enjoy from their farms. The NSSP is an agriculture project seeking raw materials to feed the Norpalm processing mill. The project aimed to sustain palm fruit throughout the farming seasons and increase palm fruit production in the RFAZ landscape. The oil palm processing mill must operate on the available raw materials, thus palm fruits. The NSSP has allowed smallholder farmers to benefit from agricultural inputs such as hybrid seeds, planting materials, and agrochemicals. The policy has satisfied the production element, such that various agricultural inputs were allocated to smallholder farmers to increase the production of palm fruits. An oil palm farmer in Pretsea said that *The NSSP has helped most farmers here. They provide fertilizer, chemicals, and extension officers who provide extension services to us. It has made me cultivate more palm fruits on the landscape.* Through the Ministry of Food and Agriculture, Ghana's government has also provided some extension services to the farmers even though a private entity like Norpalm Company has coordinated this policy. The RFAZ landscape has changed due to the persistent cultivation of oil palm plantations in the landscape. The GEP ensures sustainable agricultural production as outlined in the policy document. The framework, a twenty-year development agenda, seeks to plan the landscape of Ghana. The framework targeted enhancing sustainable agriculture through increasing food production. The policy encourages the prioritization of production and initiates several sub-policies, such as irrigation schemes, to help achieve sustainable production in the landscape. However, the policy does not focus on cash crop production in the policy documents. The GNSDF was much more interested in improving food production than in increasing the production of cash crops like rubber and oil palms in the landscape.

Element of Land management

Land management is a key production element that requires a dynamic and systematic approach to its sustainability. The review of ROPP, NSSP, GEP, and GNSDF envisages land management as a critical indicator in the production process. The land management under these policies made a significant improvement to the landscape. Interestingly, before the ROPP, the land was not expensive in the landscape. This insight was revealed in an in-depth interview with a rubber farmer in the Gyambra community. *Thirty (30) years ago, this community's land was not expensive. Now, the ROPP directly influences land prices such that smallholder farmers and private individuals are willing to lease their lands for rubber plantation. The ROPP has prioritized land as a major input in the production value chain*. The land management element under the production pillar of the ROPP is key to land use planning in the RFAZ. It also directly impacts production in such a way that the availability of land might increase the chance of sustaining agricultural production.

The NSSP significantly improved land management in the landscape after the policy was implemented. After implementing the NSSP, most farmers were diverted to rubber cultivation, threatening land management elements of the landscape production pillar. A farmer from the Apowa community said that *land management is a major issue under the NSSP. Though the project required us to have land, most farmers diverted to rubber cultivation, which gave us more income. Hence, land management is an issue because no one controls what we use our lands for in the community*. Before implementing the NSSP, most farmers were into oil palm plantations and other food crop cultivation. Now, the policy has contributed to the loss of oil palm lands to rubber plantations, threatening land management elements regarding oil palm production.

The GEP promotes sustainable use of land in an agricultural economy. It regulates the use of toxic and harmful chemicals to safeguard the environment, which was outlined in the policy document. The GNSDF concentrated on how to increase cultivated lands, especially croplands.

Though the policy seeks to manage land efficiently in the lands, the policy is biased toward cash crop production by giving more attention to food crops. The GNSDF prefers to allocate land along the major central truck roads. The policy identifies and designates land with high or potential agricultural value.

Element of Production systems

The element of the production system points out the production strategies and mechanisms employed for sustainable agriculture in the RFAZ. The ROPP, NSSP, GEP, and GNSDF were reviewed concerning production systems. The production system looked at the production process in the cash crops (rubber and oil palm) production value chain. The ROPP outlined various production stages from planting to harvesting. The ROPP aimed to produce high-quality rubber that meets international standards by adopting modern production and processing systems. Before the ROPP, rubber farmers did not require chemicals for rubber plantations. Again, most of them do not know about the rubber nursery. However, implementing ROPP has enlightened out-growers on how to harvest rubber latex from their farms. The policy has also entreated them to use farming equipment from GREL to enhance production. One rubber farmer in Apemenim confirmed that; The ROPP beneficiaries have access to tapping equipment, which encourages rubber latex production *in the RFAZ. After the implementation of the ROPP phase 1, I was trained by GREL officials to tap the rubber latex during the harvesting stage.* This indicates that ROPP satisfied the production systems elements of the production pillar.

Under the NSSP, the production system used before the policy was labour-intensive, and smallholder farmers used peasant tools rather than modern machinery on their farms. However, the implementation of NSSP has emerged in the transportation of oil palm bunches from individual farmers to the Norpalm processing mills. The NSSP also improves mechanisms involved in oil palm cultivation. Again, the production system adopted during this project somehow discourages some smallholder farmers from proceeding with oil palm cultivation. The GEP emphasized the production system to use to ensure free environmental damage. The policy stressed sustainable environmental strategies to be adopted in the agricultural landscape. In recent times, the influence of GEP has been appreciated in the production system whereby various agricultural systems in the landscape are in tune with the GEP of elements of the production system in the GNSDF but do not focus on the production systems in sustainable agriculture. The GNSDF has failed to examine the production systems employed during this policy. The GNSDF, though, is a spatial development policy aimed at developing the agriculture spatial; it does not focus on production systems that can alternate the RFAZ.

Landscape Pillar of Conservation

This pillar seeks to conserve, maintain and restore biodiversity and ecosystem services. It also focused on limiting the degradation of the landscape by optimizing landscape connectivity. The conservation pillar is important to landscape ecology. Conservation respects socio-ecological integrity by restoring and managing ecosystems. The section assesses the key conservation elements, such as biodiversity, natural resource management, and ecosystem services in agricultural land use policies, as displayed in Table 5.

Element of Biodiversity

Biodiversity, an indicator of conservation, plays a significant role in the landscape management of the RFAZ of Ghana. The element of biodiversity concentrates on ecological structure and space for living organisms in the landscape. The study evaluated ROPP, NSSP, GEP, and GNSDF.

The ROPP, whose primary target was to provide raw materials to feed the rubber processing industries, has an ecological bias to biodiversity. Before the implementation of the ROPP, the landscape was mainly dominated by forests and other ecological features that contribute to biodiversity. An in-depth interview with an official from the forestry division had this to say: *The implementation of ROPP harms biodiversity conservation. Before the ROPP, most forest areas were homes for diverse species. However, the clearing of forest areas for rubber plantation has been our major headache after the ROPP has been implemented in the RFAZ.* The ROPP does not feature biodiversity; thus, no sub-policy under the ROPP tries to protect the animals and their environments. Though management has pointed out conservation plans, the ROPP pushes farmers to clear more forest lands for rubber cultivation. A rubber farmer in the Abura community voiced that *the expansion of rubber plantations has destroyed several forest areas, which violates the ecological status of the RFAZ. The requirement to be a beneficiary of the ROPP is access to land; hence, we do not have any option other than to convert our croplands or forest lands into rubber plantations*.

The NSSP outlined a sub-policy known as the High Conservation Value Area (HCV), which respects ecological integrity in the landscape.

Before the implantation of the policy, most farmers were into oil palm cultivation. The initiation of the Norpalm oil company has outlined strategies such as no hunting, burning, lumbering, or farming in the forest-reserved area. These strategies have satisfied the conservation pillars of the RFAZ, explicitly focusing on protecting biodiversity in the landscape. The plantation manager of Norpalm Oil Company confirmed that HCV implementation *is an initiative to encourage biodiversity conservation among farmers. The HCV adequately restores and maintains biodiversity surrounding the local communities.* Again, the HCV instructed that there should be no clearing of vegetation along wetlands and ponds in the landscape, or else the clearing can endanger species in their habitats. Hence, the policy satisfied the biodiversity elements.

The GEP protects habitats and landscapes from degradation and depletion of natural resources. Before the GEP, the Forestry Commission sought to preserve the forest areas in the RFAZ. Implementing the GEP assists the mandate of the forestry commission to ensure the conservation of biodiversity in the landscape. This role satisfies the biodiversity element of the conservation pillar in the GEP.

The GNSDF, as noted for strengthening spatial development across the landscape of Ghana, has made a limited contribution to biodiversity. The policy focuses on improving economic viability markets and tackling urbanization. The element of biodiversity that contributes an essential quota to ecological integrity lacks space in the GNSDF.

Element of Natural Resource Management

Natural resource management is vital for landscape planning and management in the RFAZ. It considers natural resources such as minerals, wetlands, and forests, which are important in the socioecological system. Consequently, the ROPP does not make room for natural resource management in the landscape. The ROPP goals do not include the protection of natural habitats. Before the implementation of the ROPP, most parts of the landscape were forest-dominated. The ROPP has enabled the cultivation of rubber around the forest reserves. The competition for land among local communities has resulted in the degradation of natural resources like wetlands. An in-depth interview with an official from the forestry division lamented that *the cultivation of rubber plantations in the RFAZ endangers natural resource management, especially forest reserves. Most of the lands, including wetlands, are now used for rubber plantations; meanwhile, 30 years ago, these issues were not there.* The policy has no sub-policy that entreats natural resource management on the landscape.

The NSSP directly influenced natural resources, such that natural resources were conserved and protected, especially in the plantation zones. Before the NSSP was initiated, there was a clearing of vegetated areas in the RFAZ that served an ecological purpose. However, the implementation of HCV, a sub-policy of the Norpalm oil company, stated clearly that no forest clearing should be done beyond 60 meters along water bodies with a width of more than 20 meters. The policy also demands no replanting and development activities on slopes greater than 30 degrees and on slopes greater than 30 degrees. The NSSP agrees with ecological integrity, which meets natural resource management criteria in the landscape.

The GEP stresses the implementation of environmental plans that manage natural resources. The policy regulates the exploitation of natural resources. Before the policy, local communities degraded local resources. After the implementation, illegal activities such as small-scale mining and illegal lumbering hampered the successful management of natural resources. The policy protects the environment from degradation, which is another illegal activity.

Natural resource management under GNSDF was considered in the policy. The GNSDF ensures the sustainable development and protection of ecological assets. The policy also stresses the principle of environmental sustainability, such that protecting the natural environment is a goal for economic development. The implementation of GNSDF seeks to protect and restore natural habitat systems and open spaces in the landscape.

Element of Ecosystems Services

The ecosystem services under the conservation pillar of landscape point out the services derived from RFAZ through ROPP, NSSP, GEP, and GNSDF.

The ROPP does not contribute to the conservation of the landscape. Formally, local communities derived ecosystem services such as wood for fuel, food, clothing, and other service from the landscape. The implementation of ROPP has distorted these services; thus, lands that provide this resource were used for rubber plantations. This disqualifies the ROPP in terms of satisfying the ecosystem services element in the landscape because the ROPP did not outline regulations and procedures that guide the conservation of the landscape.

The NSSP, which set out a conservation plan for managing ecological assets in the landscape, has provided ecosystem services for smallholder farmers and local communities. Though the HCV plan was implemented to restore the ecological integrity of the landscapes, it would also aid smallholder farmers in benefiting from ecosystem services. Before the implementation of NSSP, the farmers were benefiting from ecosystem services. The HCV policy has complemented the benefits of ecosystem service by giving out strict regulations for protecting the landscape.

The GEP is centred on protecting and regulating activities in the ecological landscape. The mandate of the policy also helped provide ecosystem services; hence, it satisfies the ecosystem elements.

The GNSDF does not acknowledge ecosystem services in its policy. Though the policy emphasized spatial development of the agricultural landscape, the GNSDF has failed to look at ecosystem services. There is no clear indication of how ecosystem services could be explored on the landscape.

Landscape Pillar of Livelihood

This part of the study assesses the landscape pillar of livelihood, which looks for well-being, infrastructure, and human settlement dimensions in the agricultural land use policies.

Element of wellbeing

The element of well-being is an integral component of the livelihood pillar, which helps to understand the human systems in the landscape. The element of well-being was critically assessed among the ROPP, NSPP, GEP, and GNSDF. The study identified that ROPP employed more than 80% of rural communities in the RFAZ. Before the implementation of ROPP, the unemployment and poverty rates among the rural communities were high, but

ROPP has at least reduced them in the RFAZ. An in-depth interview with one rubber farmer confirmed this: *The ROPP, through the Rubber Outgrowers and Agents Association, helped me access credit facilities to establish my rubber plantation*. Again, a GREL official also emphasised the local communities' employment status. He said this: *The ROPP provided job opportunities to local communities in the RFAZ. This intervention has improved smallholder farmers' well-being, especially by engaging 20% of women in the local communities in rubber plantations. Under this policy, health insurance plans for medical treatment were rolled out for smallholder farmers under ROOP*. This development among the rubber farmers has improved their well-being in the landscape. Hence, the ROPP ascertains the element of well-being of the livelihood pillar.

The NSSP objective was to improve the well-being of smallholder farmers in oil palm production. Though the NSSP focuses on production, the policy is concerned about the well-being of smallholder farmers, thus ensuring that oil palm plantation is beneficial or profitable to smallholder farmers while meeting production targets. Before the scheme was introduced, palm cultivation had been the leading cash crop in the landscape despite the high poverty rate among rural communities. However, the introduction of NSSP has focused on reducing poverty among smallholder farmers in RFAZ.

The GEP promotes a clean environment across the entire landscape, improving human well-being. The GEP regulates pollution in the landscape. Initially, before the GEP was implemented, RFAZ suffered environmental degradation, especially along areas nearer to water bodies and wetlands. The adoption of GEP has protected green spaces in the landscape, satisfying the well-being element of livelihood.

The GNSDF also satisfies the element of well-being such that the policy structures agricultural lands in a way that will improve human well-being. The policy focused on employing farmers and other communities. This directive in the policy satisfies the element of well-being.

Element of Infrastructure

The ROPP has outlined several infrastructure development plans for the local communities in the RFAZ. The ROPP generously provides infrastructure that benefits smallholder farmers and local communities—before implementing ROPP, local communities, especially those in the rubber plantation hubs, lacked some basic amenities. However, the implementation of ROPP through ROAA advocated for the development of infrastructures such as schools and health centres and the rehabilitation of roads. An in-depth interview with a rubber farmer in the Abura community said that *GREL has done well in our community. They established a health centre that served the entire community. Previously, when there was no health centre, we needed to attend health care in Agona, which was sometimes stressful. They also rehabilitated our feed roads, which led to our rubber farms.* This development has qualified the infrastructure element and helped improve smallholder farmers' livelihood in the RFAZ landscape.

The NSSP has adopted CSR in the form of infrastructure development. The policy aims to provide socio-economic benefits to the surrounding local communities by providing livelihood to smallholder farmers. In the past, Norpalm only focused on producing and processing palm fruits, but the evolution of NSSP has benefited oil palm plantation communities' regarding infrastructural development from the Norpalm oil company. Thus, the NSSP does not only concentrate on the cultivation of oil palm plantation for smallholder farmers but accomplish their CSR by providing infrastructure to the surrounding communities in the landscape, which aid in smallholder livelihood.

The GEP encourages infrastructure development. The policies align their objectives with sectoral policies to develop sustainable infrastructure. The GEP ensured that infrastructures on the landscape do not negatively affect the physical environment.

The GNSDF was anchored on infrastructure development to promote agriculture and other economic activities. The policy satisfies the infrastructure element in that special area that will be connected through landscape corridors. The policy emphasises the adequate provision of storage and transportation networks that foster economic development on the landscape.

Element of Human Settlement

The element of human settlement under the livelihood pillar of the landscape looked out for land planning toward the development of settlement in the RFAZ. The ROPP, NSSP, GEP, and GNSDF were reviewed against the settlement planning and expansion benchmark.

The ROPP does not consider settlement planning in its policy. The ROPP only focuses on rubber cultivation and how the plantation could assist smallholder farmers in enjoying a sustainable income. The ROPP does not factor land planning or settlement expansion into their policy. The ROPP serves as an eye-opener to smallholder farmers willing to convert forest and bare land to rubber plantations. A 54-year-old farmer in Apemanim lamented that *The individual landowners have sold and rented most of the lands for rubber development. We cannot even have access to land for building in this community*.

An in-depth interview with an official from the Ahanta West district assembly said this: *In the past, people could easily access land for building. Now, we are experiencing the opposite: bare land areas are now rubber plantation areas because farmers gain more income from rubber than from any other crop.*

The NSSP does not consider the element of human settlement in the policy. The NSSP also had a similar situation under the ROPP, such that the direction of NSPP policies was not targeting settlement growth alongside the development of large plantations of oil palms by smallholder farmers. The GEP and GNSDF considered the element of human settlement, which targeted land use planning toward a sustainable agricultural landscape. For instance, the GEP helps to integrate population planning and environmental sustainability. It also ensures proper planning of settlement, which enhances a sustainable environment. The GNSDF, on the other hand, considered settlement planning in the policy, which gives guidelines as to what the landscape should envisage in the year 2035.

Effect of Agricultural-land use policies' Impact on landscape change in the Rain Forest Agro-ecological Zone

This section focuses on the implications of agricultural-land use policies on the Rain Forest Agro-ecological landscape. The section also highlights respondents' demographic characteristics, drivers of landscape changes, landscape dynamics, and implications on food security and human wellbeing.

Demographic characteristics of respondents

Table 6 summarises the demographic characteristics of respondents in the RFAZ.

Table 6:Demographic characteristics of respondents

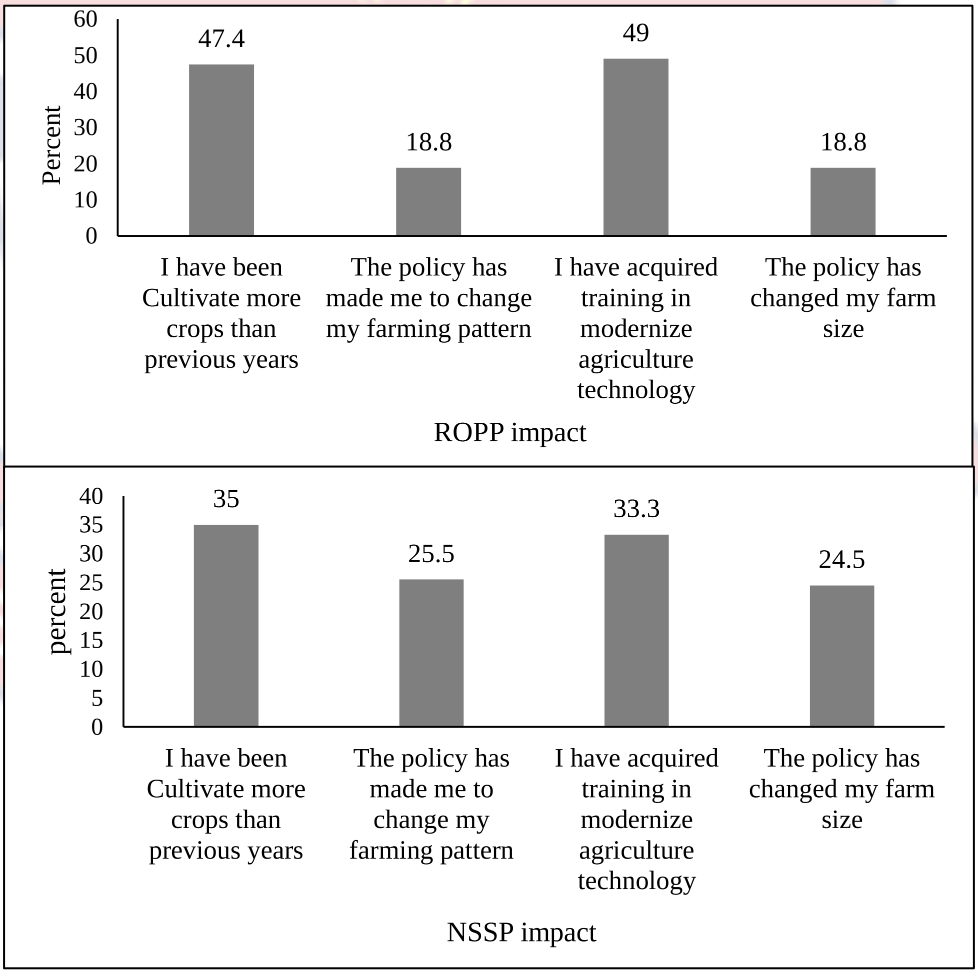
Variable	N	%		N	%
Gender			**Income**		
Male	163	84.9	Low	82	42.7
Female	29	15.1	Middle	54	28.1
Age			High	56	29.2
Young adult	73	38.0	**Years of experience**		
Middle age adult	58	30.2	10-14 years	74	38.5
Old aged adult	61	31.8	15-18 years	60	31.3
Religious Affiliation			19- 36 years	58	30.2
Christian	119	62.0			
Muslim	42	21.9	**Access to farmland**		
Traditional	31	16.1	Self	97	50.5
Education Level			Rent	34	17.7
No formal education	63	32.8	Family	24	12.5
Basic	97	50.5	Friend	20	10.4
Secondary	24	12.5	Private	17	8.9
Tertiary	8	4.2	**Farm management**		
Marital status			Self	103	53.6
Single	8	4.2	Husband	53	27.6
Married	175	91.1	Wife	10	5.2
Divorced/separated	6	3.1	Children	13	6.8
Widow	3	1.6	Non-family member	13	6.8
Type of crop cultivated.					
Rubber	128	66.7			
Oil palm	64	33.3			

Source: Adzigbli (2022)

The study sampled 192 respondents, mostly dominated by males (84.9%), with females representing only 15.1%. In the study area, most respondents (81.9%) were older adults (55 years and above), with only 20.2% being young adults. Most respondents (64.3%) were affiliated with Christianity, while Muslim and traditional accounted for 24.4% and 11.3%, respectively. Also, more than half (50.2%) of the respondents have attained primary education, while those with secondary and tertiary education were 10.7% and 4,2%respectively. The proportion of respondents who had no formal education was 34.5%. Regarding marital status, 91.1% were married, 4.2% were single, 3.6% were divorced/separated, and 1.2% were widows. Most respondents (66.7%) engaged in a rubber plantation compared to an oil palm plantation (33.3%).

Again, 29.2% of the respondents fall within the high-income category, middle-income (28.1%), and 42.7% low-income. However, 38.5% of respondents had working experience between 10 and 14 years, 31.3% (15-18 years), and 30.2% had experience between 19- 36 years. Regarding access to farmland, 50.5% of the respondents own their farmlands, 17.7% had access to farmlands by rent, and 12.5% were family-owned lands. Further, 10.4% of the respondents accessed the farmlands through friends, whereas 8.9% were private lands. More than half of the respondents (53.6%) manage their farms, whereas husbands manage 27.6% of the farms. A low proportion of respondents assigned the farm management role to their wives (5.2%), children, and non-family members, representing 6.8% each.

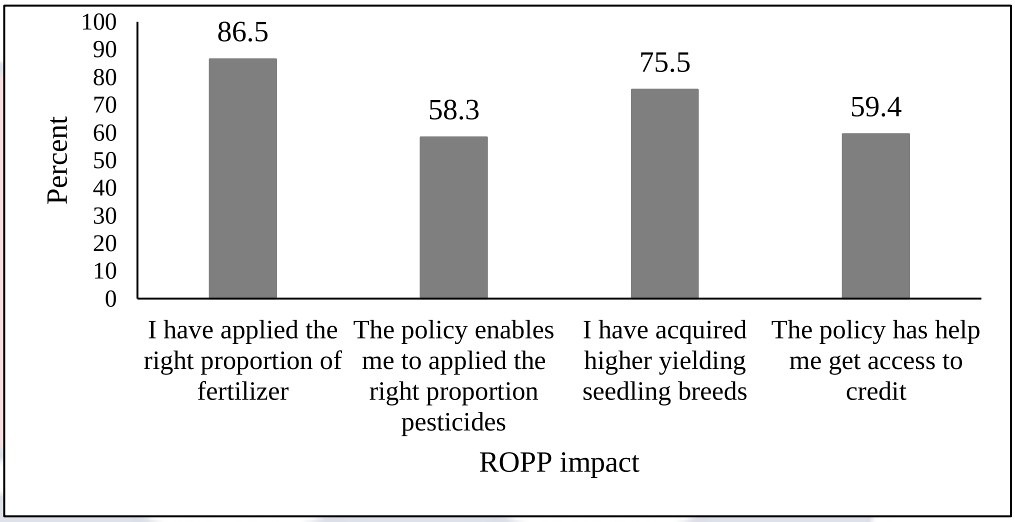
The highest percentage (86.5%) of respondents reported that applying the right proportion of fertilizer was achieved under the ROPP policy as an agricultural input in the landscape (Figure 4). The finding further indicated that more than half of the respondents reported that the ROPP policy impacted their agricultural input through the acquisition of higher seedling breeds (75.5%), access to credit (59.4%), and application of the right proportion of pesticides (58.3%). The NSSP impact on agriculture inputs indicates that 64.6% of the respondents agreed that the NSSP has enabled them to apply the right proportion of fertilizer, while 45.8% contribute to acquiring higher-yielding seedling breeds. The respondents also confirmed that the NSSP had pushed them to have access to credits and applied the right proportion of fertilizers, representing 33.3% and 32.3%, respectively (Figure 4).



Source: Adzigbli (2022)

*Figure 4:*Percentage distribution of agriculture inputs under ROPP and NSSP

The result shown in Figure 5 indicates that almost half of the respondents (49%) agreed that the ROPP has helped them to acquire training in modern agriculture technology.



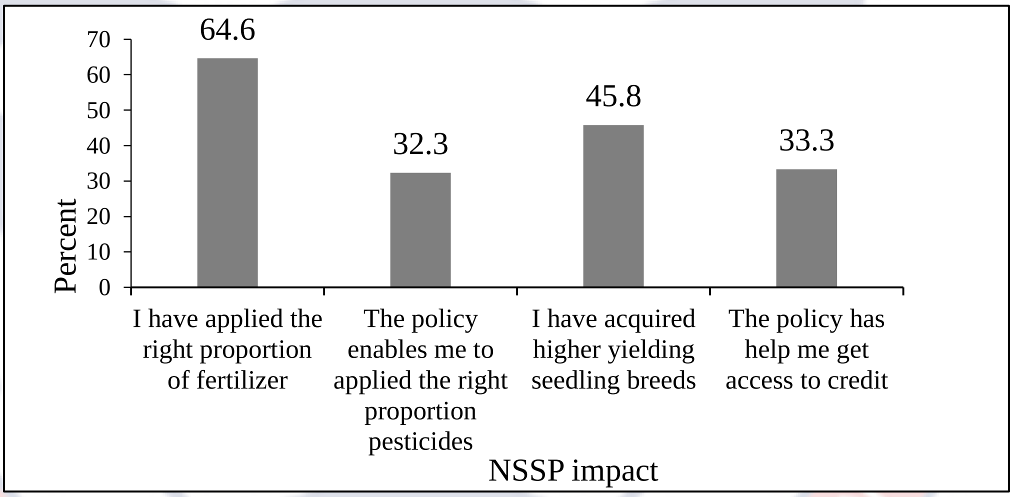


Figure 5: Percentage distribution of agriculture benefits under ROPP and NSSP
Source: Adzigbli (2022).

A similar proportion of respondents reported cultivating more cash crops (rubber) than in previous years (47.4%) under ROPP. Again, 18% of the respondents reported that the ROPP has benefited them, so the policy has changed their farm size and farming pattern, respectively. On the other hand, the NSPP's impact on agricultural benefits revealed that less than half of the respondents, 35%, accept that the policy has helped them cultivate more cash crops (oil palm) than in previous years. A similar proportion of respondents confirmed the impact of the NSSP policy assisting them in acquiring training in modern agriculture technology (33.3%). The proportion of respondents who agree the NSPP has changed their farming pattern and farm sizes accounted for 25.5% and 24.5% in the rainforest Agro-ecological zone.

The result in Figure 6 indicates the percentage distribution of policy impact on conservation for ROPP and NSSP.

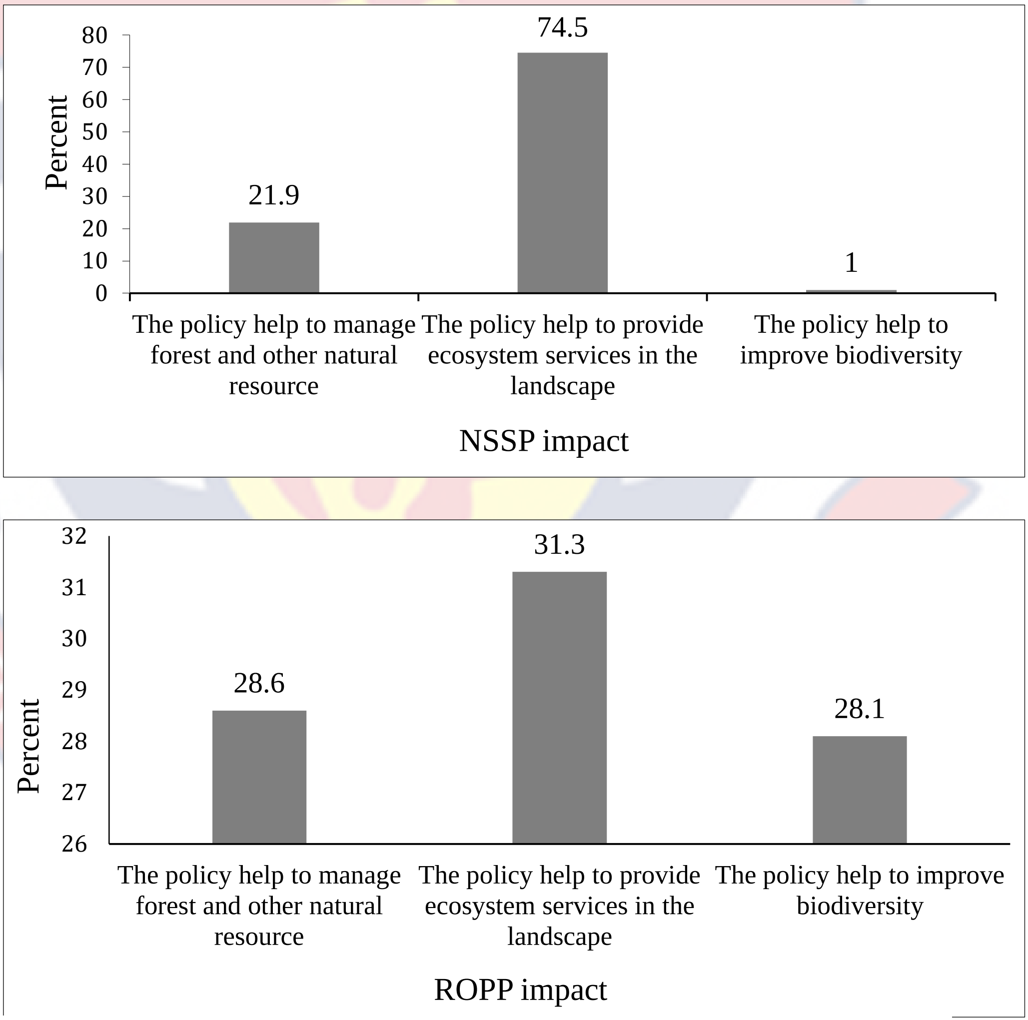


Figure 6: Percentage distribution of on conservation under ROPP and NSSP
Source: Adzigbli (2022)

Most respondents (31.3%) under ROPP agreed that the policy provided ecosystem services in the landscape, while 28.6% recorded that the policy helped manage forests and other natural resources. A similar proportion (28.1%) agreed that the ROPP has helped improve biodiversity in the landscape. The NSSP impact on conservation shows the highest percentage (74.5%) of respondents regarding the NSSP providing ecosystem services compared to 21.9% who recorded the policy helped to manage forest and natural resources. Surprisingly, only (1%) of the respondents agreed on the NSSP's impact on biodiversity conservation.

The majority of the respondents indicate that the ROPP and NSSP had an impact on infrastructure development. More than half of the respondents (58.9%) agreed that the new schools had been constructed in the community through ROPP. The respondents also recorded that new roads have been constructed and habilitated (46.4%). A small proportion of respondents under the ROPP agreed that new hospital facilities have been constructed and renovated (26%), and water and sanitation have been improved in the community, representing 11.5%. The NSSP impact on infrastructure development shows a minimal proportion of respondents accepting the impact of the policy. Thus, 14.1% confirmed that new roads had been constructed and rehabilitated, 3.6% (water and sanitation have been improved), 3.1% (new schools have been constructed), and 1.6% (new hospital facilities have been constructed and renovated in the landscape) as depicted in figure 7.

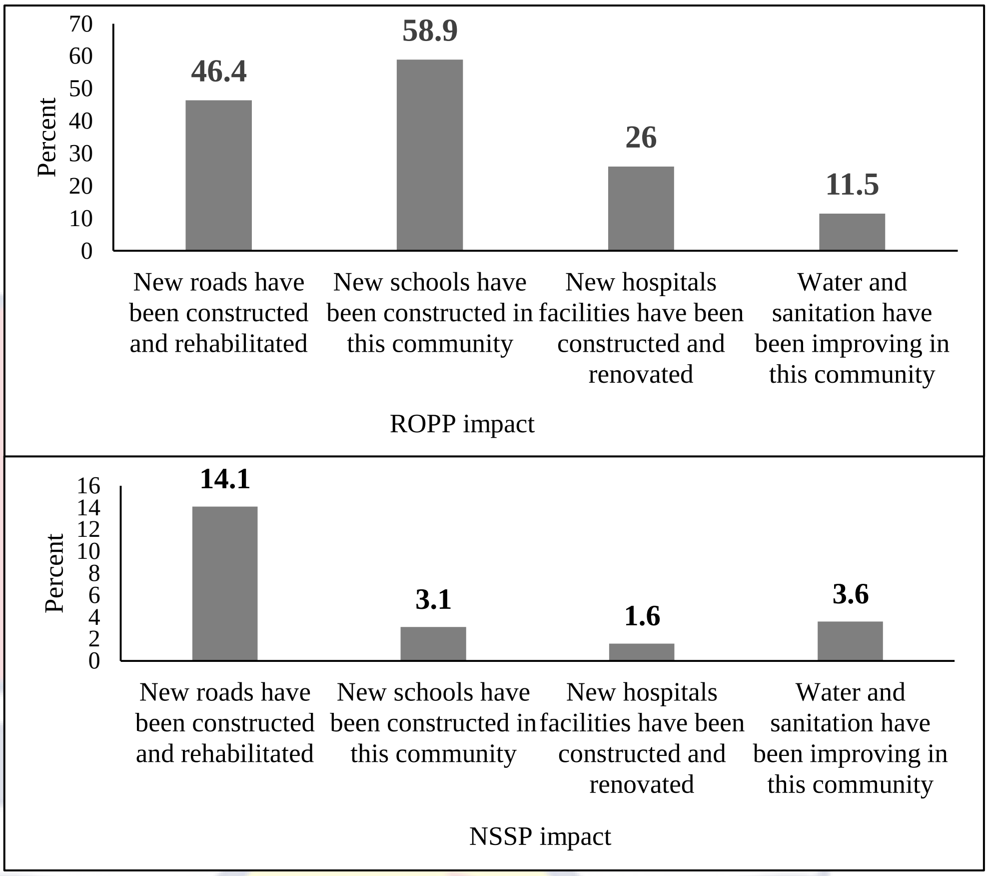


Figure 7:Percentage distribution of agricultural policy impact on infrastructure development.
Source: Adzigbli (2022)

The percentage distribution of ROPP and NSSP impact revealed that most respondents under ROPP commented that the policy had improved their monthly income (89.6%), while the same proportion of respondents (72.9%) revealed the ROPP had increased their livelihood and well-being respectively. In NSSP, less than half of the respondents (44.8%) agreed that the policy has increased their livelihood, 37% pointed out that it has improved their well-being, and 31.8% indicated it has improved their monthly income (Figure 8).

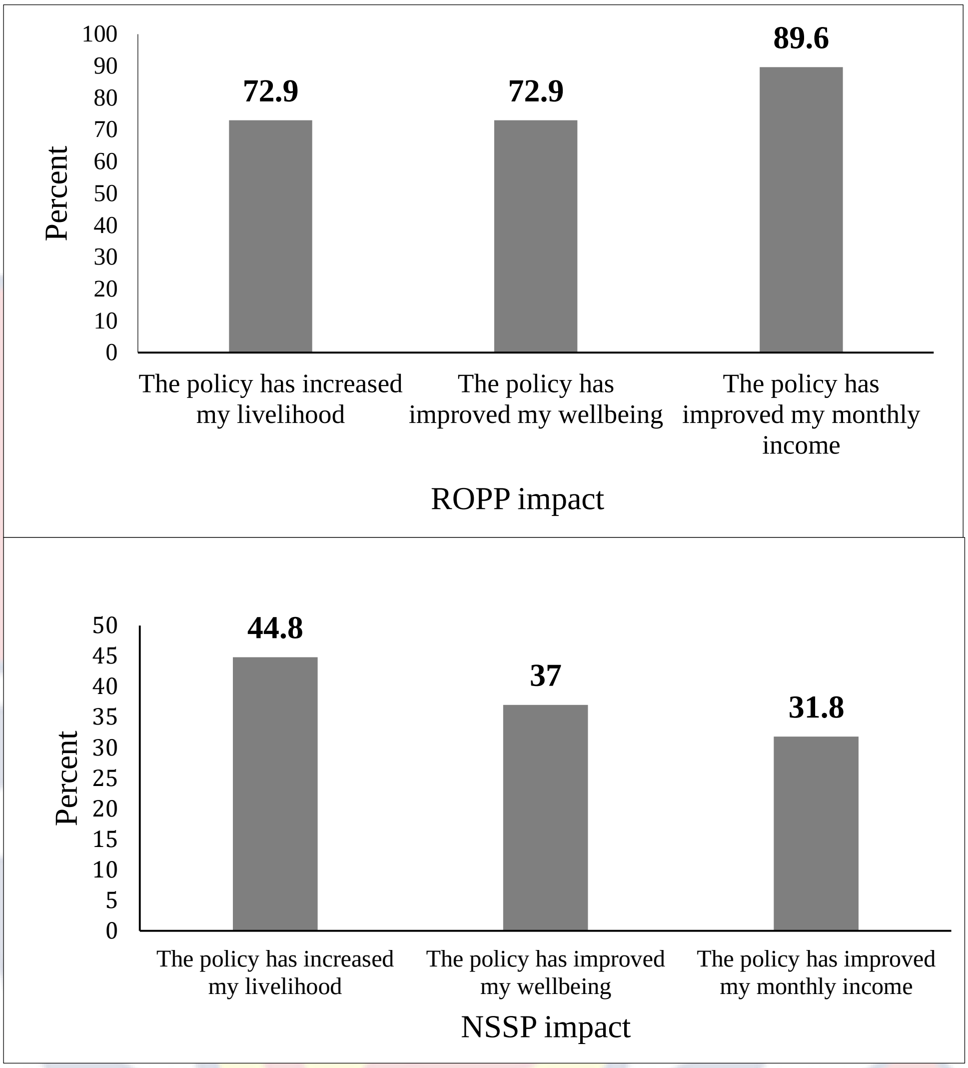


*Figure 8:*Percentage distribution of agricultural policy impact on livelihood under ROPP and NSSP in the Rainforest agro-ecological zone
Source: Adzigbli (2022)

The result of bivariate analysis in Appendix B shows that education level (p=0.062) was statistically significant with landscape changes. The socio-demographic characteristics like sex, age, religious affiliation, marital status, type of crop cultivated, years of farming experience, farm ownership, and farm management were not statistically associated with landscape change. Further, regarding impact, only infrastructural development, specifically new roads halted and renovated (p=0.016) and new hospital facilities that h However, ROPP's impact on agriculture input, conservation, and livelihood was not statistically associated with landscape change. On the other hand, it is surprising that only livelihood (the policy has improved my livelihood) was statistically significant (P=0.038) association with landscape change among the NSSP impact. Further, agricultural inputs, benefits, and conservation impact were not statistically different between ROPP and NSSP.

Concerning the level of landscape change in the RFAZ, most respondents perceived the change as either low, moderate, or high. More than half of the respondents in Abura (56.2%) and Egyambra (53.1%) perceived the landscape change level as high compared to respondents from other communities in the RFAZ. The same proportion of respondents (46.9%) in Apemanim and Sankor perceived landscape change as moderate. Further, 34.3% of the respondents consider the level of landscape change to be low in Sankor, Apowa (31.3%), Apemanim (25%), Abura (21.9%), Pretsea (15.6%) and Egyambra (12.5%) respectively (Figure 9).

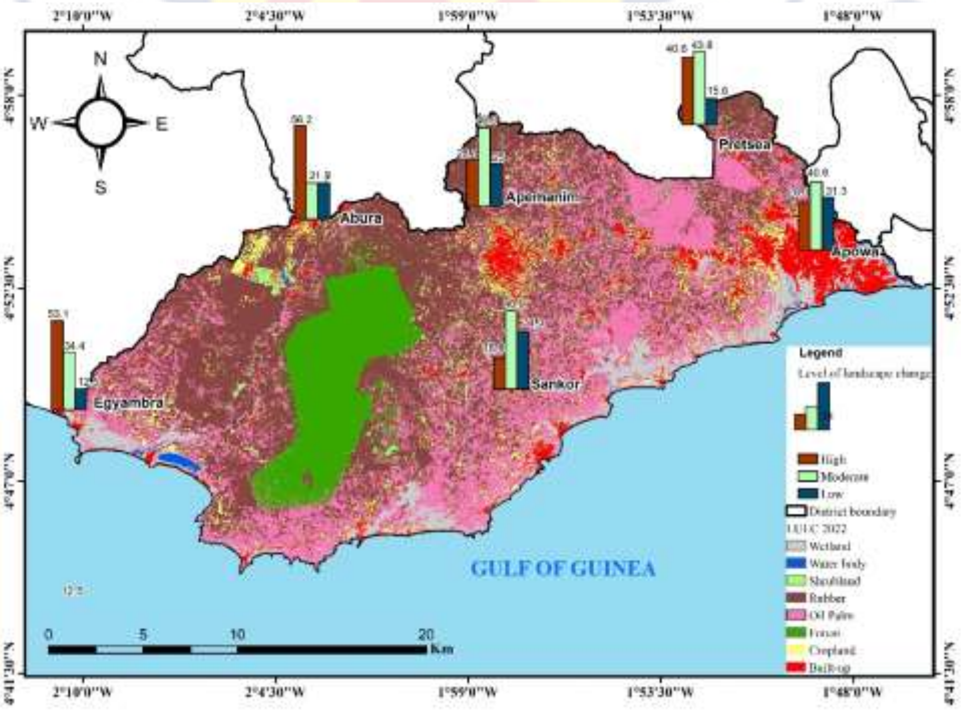


*Figure 9:*Spatial distribution of the level of landscape change
Source: Adzigbli (2022)

Binary Logit regression analysis of the effect of agricultural-land use policies on landscape changes

The result indicates that agricultural-land use policy impact on agriculture inputs (OR= 1.04, 95% CI = 0.442, 1.642) and agriculture benefits (OR= 1.85, 95%CI = 1.248, 2.456) were statistically significant ($p<0.05$) to influence landscape change in the RFAZ. However, conservation 1.85(95%CI =1.248, 2.456), infrastructure development 1.85 (95%CI = 1.248, 2.456), and livelihood -0.11 (95%CI= 1.248, 2.456) were statistically insignificant ($p>0.05$) to predict landscape change under the ROPP as indicated in Table 7. Further, the results under the NSSP indicate that agriculture benefits (OR= -0.809, 95% CI = -1.317, -0.300) contribute to landscape change in the landscape. The rented lands 20.045 (95% CI = 18.600, 21.490) had a higher odd compared to family 19.675 (95%CI=18.089, 21.261), self1 9.318(95%CI=18.032, 20.603), private 18.806 (95%CI=16.945, 20.667), and government lands 18.180 (95%CI = 18.180, 18.180). The result further indicated that years of farming experience (OR= 1.85, 95%CI = 1.248, 2.456) and access to land had statistically significant odds influencing the landscape change in the RFAZ. However, policy outcomes on agriculture inputs, livelihood, conservation, and infrastructure development under the NSSP were not statistically significant in influencing landscape change.

Table 7: Effect of agricultural-land use policies on landscape change

				95%Confidence Interval (CI)	
Variable	OR	S. E	P-value	Lower	Upper
ROPP					
Agriculture Input	1.04	0.306	0.001*	0.442	1.642
Agriculture benefit	1.85	0.308	0.000*	1.248	2.456
Conservation	-0.34	0.309	0.260	4.918	4.918
Infrastructure development	0.03	0.258	0.885	3.346	3.346
Livelihood	-0.11	0.288	0.694	2.388	2.388
NSSP					
Agriculture Input	0.078	0.133	0.558	-0.183	0.340
Agriculture benefit	-0.809	0.260	0.002*	-1.317	-0.300
Conservation	0.298	0.293	0.309	-0.276	0.873
Infrastructure development	0.649	0.401	0.106	-0.137	1.435
Livelihood	-0.177	0.158	0.248	-0.477	0.123
Access to land					
self	18.119	0.804	0.000*	16.544	19.694
Rent	17.358	0.874	0.000*	15.644	19.071
Family	16.807	1.014	0.000*	14.820	18.794
Private	15.110	0.000	0.000*	16.110	16.110
Government	0.0000	0.0000	0.000*	0.000	0.0000
Years of farming experience	0.069	0.035	0.047*	1.587	1.587
Model fitness					
-2Log Likelihood	418.04				

Table 7 continued.

X2 (7)	289.21				
P= Value	0.00				
Pseudo R2					
Cox and Snell	0.49				
Nagelkerke	0.55				
McFadden	0.31				
N	192				

P<0.05 Reference category = high

Source: Adzigbli (2022)

Discussion

The agricultural-land use policies implemented in the RFAZ have a significant role in landscape dynamics. Although several issues were observed in the guidelines, there are three pillars considered in ROPP, NSSP GEP, and GNSDF policies. These pillars include production, conservation, and livelihood. In the ROPP policies, the attention was focused on production, thus producing to feed the rubber industries for export (GREL Report, 2016). The ROPP agenda also targeted sustainable livelihood for smallholder farmers in the local communities engaging in rubber plantations. This achievement satisfies the sustainable development goal, which focuses on alleviating poverty by 2030. Again, the impact of ROPP on the landscape was reflected through the acquisition of agricultural inputs such as fertilizer, pesticides, higher-yielding seedling breeds, and access to credit. In ROPP, agriculture input and benefits contribute significantly to landscape change, which supported a study conducted by UNCTAD (2021). The ROPP helped farmers to enlarge their farm sizes and cultivate more rubber plantations. This finding aligns with the outcome of Ullah, Mahmood, Zeb, and Kächele (2022), who stated that farmers are likely to increase their farm sizes when they can access agricultural inputs.

The NSSP policy also helped the production pillar, which targeted smallholder farmers in oil palm plantations to feed Norpalm oil companies to remain in processing palm oil. According to Khatun, Maguire-Raipaul, Asante, and McDemoot (2020), oil palm production sometimes depends on smallholders when there is a shortage of palm fruits. The effect of NSSP on the landscape was significant, with only agricultural benefits. The season could be that farmers were more interested in the project's outcome than the inputs required. Adeho (2015) revealed that outgrowers under NSPP are more likely to increase their farm sizes, acquire training in modern technology, and increase palm fruit cultivation. The policies indicated that the production of cash crops, rubber, and oil palm remains an economically valuable commodity that needs much attention in terms of production.

The GEP also associates itself with ensuring sustainable agriculture. The policy pointed to regulations towards cultivation that will improve the sustainable landscape. In GNSDF, the focus was not on cash crop production. Instead, the GNSDF concentrates on implementing sub-policies such as developing agriculture corridors that could help transport agricultural goods and services. The elements of production, including sustainable production, land management, and production system, were considered intensively under the ROPP and NSSP. The reason could be that land management, which forms an integral part of landscape management, needs informed decisions on managing the agricultural space for cash crop production. Further, spatial development policies like GNSDF only consider land management without giving much attention to production and production systems. Asuning-Brempong (2010) found that land management policies enhance sustainability in the agricultural production of RFAZ in Ghana.

The conservation pillar is made up of the conservation of biodiversity, natural resource management, and provision of ecosystem services. Interestingly, only NSSP and GEP satisfied all three conservation elements in the landscape. The conservation elements are prudent for landscape resilience, management, and land use planning in the ecological system. The agriculture-land use policies could either strengthen or weaken ecological systems and integrity if the conservation elements were underrated in the policy implementation. The NSSP and GEP could be recognized as viable englacial policies on ecosystem sustainability. The NSSP and GEP have made provision for biodiversity to be considered in managing natural resources like water bodies and forests within the scope of cash crop plantation. Again, the NSSP and GEP provide sub-policies on ecosystem services, which could help improve the socio-ecological systems of the RFAZ.

The ROPP and GNSDF policy did not pay much attention to conservation elements except the landscape element of natural resource management, especially for GNSDF. However, the lack of conservation elements in ROPP and GNSDF could threaten the ecological system of the RFAZ. This insight confirmed the findings of Osorio-García et al. (2020), which confirmed that ecological systems lose their value when policies cannot address the conservation of biodiversity in the systems. Thus, policy should be able to assist in managing forests and other natural resources.

Again, the findings from this study revealed that conservation for ROPP and NSSP does not significantly affect the landscape. The reason was that the ROPP and NSSP were the only profit-making entities that did not focus on landscape sustainability. Though the NSPP had HCV areas as a sub-policy, it did not take effect in the individual outgrow farms.

The livelihood pillar considered well-being, infrastructure, and human settlement, which was used as a benchmark for assessing ROPP, NSSP, GEP, and GNSDF. The infrastructural element was considered in all four policies. For instance, ROPP and NSSP considered infrastructural development as a

CSR by the policy actors. The policy targeted the infrastructure development component with the view that infrastructure development could help address smallholder's livelihood and well-being. Infrastructure is crucial to farmers' well-being and contributes to landscape changes. The study conducted by Asabere et al. (2020) on major metropolitan regions in Ghana confirms that persistent infrastructure development in the physical landscape changes the land cover over time. Hence, there is a need for a landscape management plan regarding infrastructural development.

The human settlement regarding land use planning and settlement expansion was not acknowledged in ROPP and NSSP policies. It could be that the policies only give attention to the well-being of smallholder farmers by providing infrastructure such as schools, community health centres, and rehabilitation of feeder roads and boreholes, among others. The GNSDF considered infrastructure and human settlement in their policy without considering the smallholder farmers' well-being. The impact of infrastructure development on the landscape change for ROPP and NSSP was not statistically significant. Though GREL and Norpalm oil companies have undertaken some CSR, the effect of infrastructure development was not significant in influencing landscape changes in the RFAZ. However, access to land was crucial for landscape change under ROPP and NSSP. This indicated that access to land is important in influencing landscape dynamics in the socio-ecological landscape; hence, crucial policies towards land access and development in the RFAZ are needed.

Chapter conclusion

In conclusion, ROPP in the RFAZ focused on sustainable rubber production to feed the GREL to process rubber latex. The rubber production systems in the landscape facilitate sustainable production and land management in the RFAZ. ROPP does not adopt a conservation approach toward landscape changes, especially focusing on biodiversity, natural resource management, and ecosystem services. The ROPP entrusts providing livelihood opportunities to smallholder farmers in the landscape through rubber cultivation. The role of NSSP in production was not different from ROPP. In terms of conservation, I pointed out that the NSSP conformed to the conservation criteria of landscape pillars such that a policy (HCV) was implemented to protect the natural environment and conserve biodiversity. The NSSP also focuses on providing livelihood to smallholder farmers on the landscape. The GEP satisfied all the landscape pillars of production, conservation, and livelihood, endorsing its relevance for land use planning. The GNSDF is a spatial development framework that enables spatial development across the landscape of Ghana; hence, it is a key element for landscape management.

CHAPTER FIVE

EXAMINE THE IMPACT OF AGRICULTURAL-LAND USE POLICIES ON THE LANDSCAPE OF RFAZ FROM 1991 TO 2022

Introduction

This section emphasizes the LULC changes in the RFAZ. The section also highlights topographical parameters in the landscape, focusing primarily on elevation, slope, and aspect. It also highlights change detections for two time intervals (1991-2008, 2008-2022). The section finally predicts future land LULC change based on the economic benefit scenario, social benefit scenario, and ecological protection.

LULC of vegetated and non-vegetated lands from 1991-2022

The spatial analysis indicated vegetated and non-vegetated lands in the RFAZ (Figure 10). In this study, vegetated land includes all land surfaces that exhibit a patch of vegetation cover. Non-vegetated areas are made up of surface areas that do not have vegetation cover. In 1991, the vegetated lands (52748.54 ha) recorded 95.1% of land cover in the landscape, while non-vegetated lands (2710.08ha) accounted for about 4.9%. In 2008, vegetated land cover (52219.62 ha) decreased to 94.1%, while non-vegetated areas (3249 ha) increased gradually by 1%. The vegetated lands (47259 ha) depreciated in 2022 by 8.9%, representing the highest loss in vegetated land cover. Again, non-vegetated areas of the RFAZ landscape experienced a twofold increase (14.8%) in non-vegetated land cover compared to non-vegetated areas in 2008. The study also revealed that the expansion of non-vegetated areas in 2022 was concentrated in the landscape's eastern portion (Figure 10).

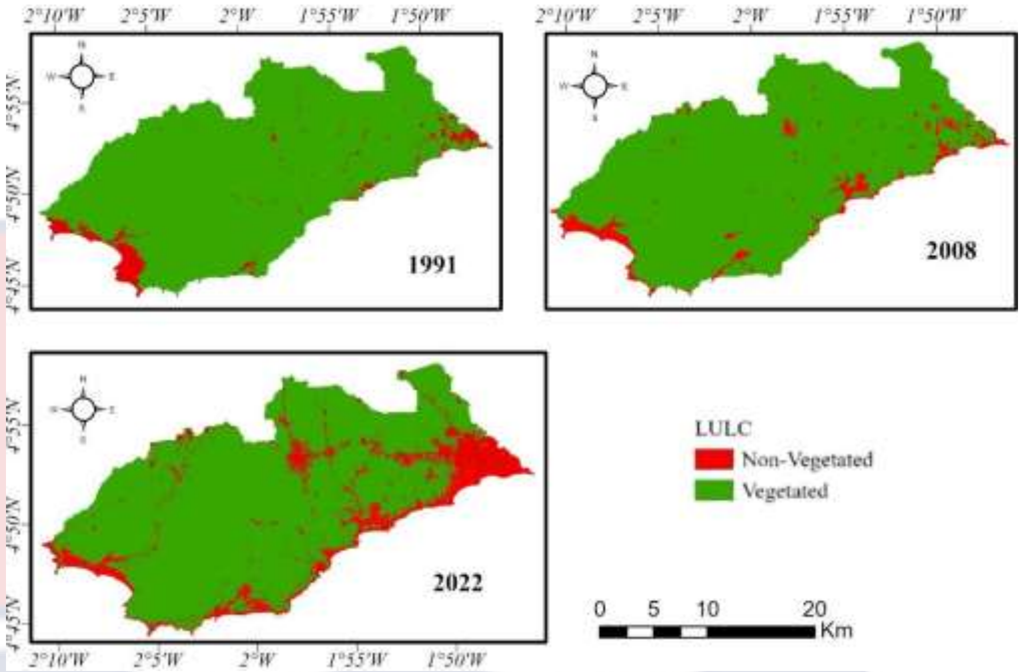


Figure 10: LULC map of vegetated and non-vegetated lands Rain Forest Agro-ecological Zone of Ghana for 1991, 2008 and 2022
Source: Adzigbli (2022)

Topographic analysis of the Rain Forest Agro-ecological landscape

The topographic parameters such as elevation, slope, and aspect were derived from the analysis of DEM from the study area. Figure 11 depicts the spatial representation of topographic parameters in the Rain Forest Agro-ecological landscape, primarily elevation (1), slope (2) and aspect (3). The highest elevation of the landscape was recorded at about 261 meters, while the lowest elevation was recorded at less than 24 meters.

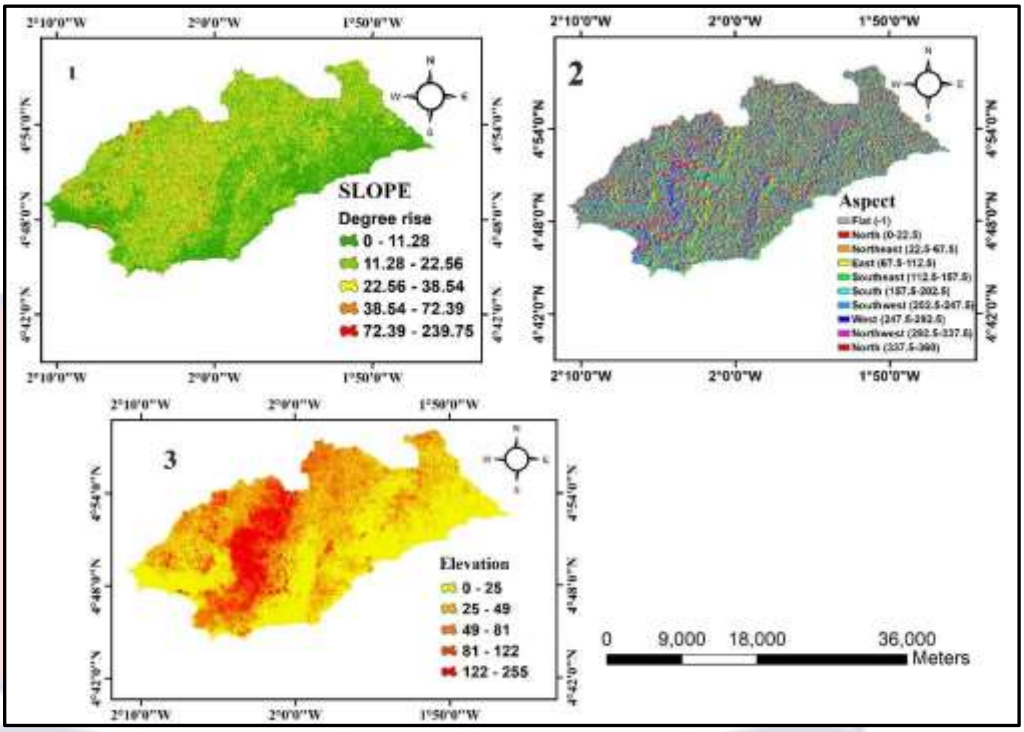


Figure 11: Topographical map of Land surface Slope (1), Aspect (2), and Elevation (3)
Source: Adzigbli (2022)

The areas experiencing a very high elevation were around forest zones and some parts of oil palm and rubber plantations ranging between 120 to 261 meters (49.03%). These areas are projecting inland toward the southwestern portion of the landscape. The lowest elevation in the landscape was recorded at less than 24 meters along the coastline and some areas towards the southeastern part of the Rain Forest Agro-ecological landscape, representing 4.6% cover of the landscape. The Agro-ecological landscape has a gentle slope of less than 5 degrees and is mostly located along the coastline, covering about 4.41% of the landscape. The landscape is generally associated with a very steep slope (26.29-65.72 degrees) in the forest zone, with some areas exhibiting steep or strong slopes of about 16.75 to 26.39, representing 52.64% and 21.06%, respectively. The landscape of the Rain Forest Agro-ecological Zone experiences a moderately gentle slope (10.56-16.75 degrees) and slopes ranging between 5.51-10.56 degrees, covering 13.41% and 8.45%, respectively. The majority of the slopes facing the northern direction of the landscape covered about 20%, representing the highest percentage of cover of the landscape. The slope facing northwest covers about 18.76%, while west and southwest aspects cover about 16.25% and 13.75, respectively. The aspect of the south (157.5-202.5) and southeast (112.5-157.5) contributed about 11.25% and 8.75%, while slopes facing east and northeast recorded about 6.25% and 3.75%, respectively.

LULC changes in the Rain Forest Agro-ecological landscape from 1991-2022

The Rain rainforest Agro-ecological landscape has been classified into eight classes via wetlands, water bodies, shrublands, forest, oil palm, built-up, croplands, and rubber based on the supervised classification presented in Figure 12. The statistics on land cover categories across 1991(a), 2008(b), and 2022(c), indicating the area extent in hectares, are presented in Table 8. In 1991, the Agro-ecological landscape was dominated by oil palm plantations (22847.94 ha), representing 41.19%, followed by forest (9627ha17.35%) and Rubber (8714ha,15.71%), respectively. A portion of the Forest Agro-ecological landscape was covered by cropland, shrubland, Water body, built-up, and wetlands, contributing about 13.72%, 6.67%, 1.95%, 1.62%, and 1.27%, respectively. In 2008, the total land cover under oil palm plantation was 20776 ha (37.45%), rubber plantation (11769ha, 21.21%), and forest (10258 ha, 18.49%) while 16.07% was covered by croplands (8918 ha). The RFAZ is also dominated by wetlands (1934 ha, 3.48%), built-up (1022 ha, 1.84%), shrublands (502ha, 0.90%), and water bodies (286 ha, 0.51%), as indicated in Figure 12 (b). In 2022, rubber plantations dominated the Rain Forest Agro-ecological landscape, covering an area of 21875 ha (Figure 12c) and contributing 39.44 %, while oil palm covered 15137 ha (27.29%). The LULC categories have indicated 10.56% LULC by forest, 7.56% by built-up, 5.99% under croplands, and 1.88% by shrublands. Part of the landscape has also been dominated by wetlands and water bodies, contributing 6.77% and 0.48%, respectively.

Source: Adzigbli (2022)

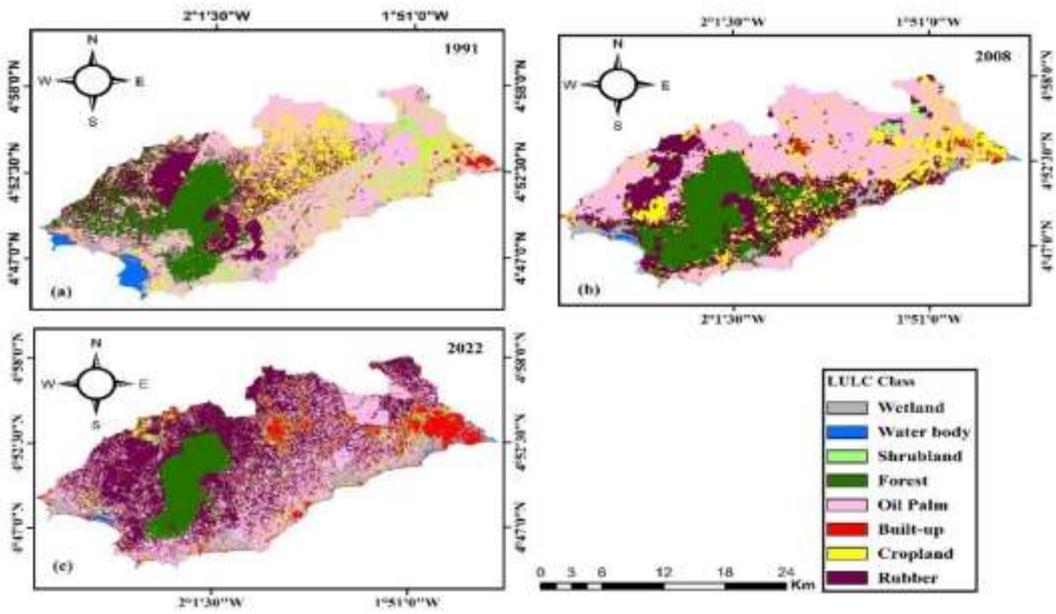


Figure 12:LULC maps of Rain Forest Agroecological Zone of Ghana for 1991(a), 2008(b) and 2022 (c)

Table 8: Spatial extent of LULC of Rain Forest Agro ecological landscape of Ghana in hectares(ha)and Percentages (%)

	1991		2008		2022	
LULU	Area (ha)	Pe cent (%)	Area (ha)	Percent (%)	Area (ha)	Percent (%)
Wetland	713.43	1.28	1930.32	3.48	3779.01	6.81
Water body	1087.02	1.96	288.72	0.52	275.94	0.50
Shrubland	3760.47	6.78	503.46	0.90	1109.88	2.00
Forest	9598.95	17.30	10255.5	18.48	5868.27	10.58
Oil Palm	22847.94	41.19	20739.06	37.38	15177.78	27.36
Built-up	909.63	1.64	1029.96	1.85	4154.67	7.49
Cropland	7720.74	13.92	8957.79	16.14	3491.46	6.29
Rubber	8820.44	15.90	11763.81	21.20	21611.61	38.96

Source: Adzigbli (2022)

The overall accuracy assessment of the pixel-based land cover maps of the Rain Forest Agro-ecological Zone in 1991, 2008, and 2022 were 91.5%, 76.5%, and 82.5%. The accuracy of the 1991 classified LULC map accords with the reference data compared to 2008 and 2022. The study recorded the lowest producer accuracy, 21.87%, for built-up in the 1991 LULC map, while shrubland and cropland had the lowest user accuracy, 47.58%, and producer accuracy, 55.31%, in 2008, respectively. For Oil palm, the study recorded 86.58 % user accuracy and 71.42% producer accuracy for the 2022 LULC map. The uncertainties in the LULC maps of the Rain Forest Agro-ecological Zone and their respective adjusted areas are located in Table 9.

Table 9: Accuracy Assessment for 1991, 2008 and 2022

	Wetland	Water body	Shrubland	Forest	Oil Palm	Built-up	Cropland	Rubber
LULC 1991								
Overall accuracy = 91.5%								
User	93.75%	93.75%	89.23%	89%	85%	87.25%	73.42%	88.81%
Producer	88.23%	75%	79.45%	91.39%	96.66%	21.87%	93.16%	90.25%
LULC 2008								
Overall accuracy = 76.5%								
User	89.92%	82.60%	47.58%	95.22%	67.55%	89.76%	49.42%	81.56%
Producer	76.14%	89.18%	77.92%	83.51%	63.65%	72%	55.31%S	78.99%
LULC 2022								
Overall accuracy = 82.5%								
User	90.25%	80%	40%	92.56%	86.58%	90.55%	60.25%	80.55%
Producer	83.33%	80.%	54.34%	87.53%	71.42%	84.56%	60%	80%

Source: Adzigbli (2022)

LULC change of the Rain Forest Agro-ecological landscape 1991-2008, 2008-2022.

The change detection analysis in Table 10 and Figure 13 indicates changes between various LULC categories in the RFAZ between 1991-2008 and 2008-2022. Shrublands (-3257.01ha, -5.87%) constitute the most significant change in the land cover between 1991-2008, with an annual change rate of -11.82%. Rubber plantation constitutes about 5.30% (2943.37ha) increase in the land cover with an annual change rate of 1.68%, followed by oil palm (-2108.88ha), which declined at an annual decreasing rate of -12.96, representing about 3.80% change in the RFAZ. Again, wetlands (1216.89ha, 2.19%), cropland (1237.05ha, 2.23%), forest (656.55ha, 1.18%), and built-ups (120.33ha, 0.21%) have increased in the land cover between 1991 and 2008 (Figure 13a), with an annual change rate of 19.31%, 0.87%, 0.38%, and 0.73%. Further, water bodies (-798.30 ha) recorded an adverse change in the landscape with an annual rate change of 7.79%.

Table 10: LULC change from 1991-2008 in the Rain Forest Agro-ecological Zone

LULC Categories	1991 **(ha)**	2008 **(ha)**	Change **(ha)**	Percent **(%)**	Annual change rate **(%)**
Wetland	713.43	1930.32	1216.89	2.19	19.31
Water body	1087.02	288.72	-798.3	-1.43	-7.79
Shrubland	3760.47	503.46	-3257.01	-5.87	-11.82
Forest	9598.95	10255.50	656.55	1.18	0.38
Oil Palm	2287.94	20739.06	-2108.88	-3.80	-12.96
Built-up	909.63	1029.96	120.33	0.21	0.73
Cropland	7720.74	8957.79	1237.05	2.23	0.87
Rubber	8830.44	11763.81	2943.37	5.30	1.68

Source: Adzigbli (2022)

Table 11 shows change detection and the annual change rate of the Rain Forest Agro-ecological Zone between 2008 and 2022. The most significant positive land cover change recorded between 2008 and 2022 in the Rain Forest Agro-ecological Zone was rubber plantations (9847.80ha, 17.75%), contributing to an annual rate of 4.34% in an increasing direction. Croplands (-5466.33ha, -9.85%) recorded the highest decreasing land cover in the landscape with an annual rate of -6.73%. Water bodies (-12.78ha, -0.02%) recorded the landscape's slowest change rate of -0.32%. Built-up (3124.71ha) experienced the fastest change rate (9.96%), followed by shrublands (606.24ha, 1.09%) with an annual rate of 5.64%, as depicted in Figure 13b.

Table 11: LULC change from 2008-2022 in the Rain Forest Agro-ecological Zone

LULC Categories	2008 **(ha)**	2022 **(ha)**	Change **(ha)**	Percent **(%)**	Annual change rate **(%)**
Wetland	1930.32	3779.01	1848.69	3.33	4.79
Water body	288.72	275.94	-12.78	-0.02	-0.32
Shrubland	503.46	1109.88	606.24	1.09	5.64
Forest	10255.50	5868.27	-4387.23	-7.90	-3.98
Oil Palm	20739.06	15177.78	-5561.28	-10.02	-2.22
Built-up	1029.96	4154.67	3124.71	5.63	9.96
Cropland	8957.79	3491.46	-5466.33	-9.85	-6.73
Rubber	11763.81	21611.61	9847.80	17.75	4.34

Source: Adzigbli (2022)

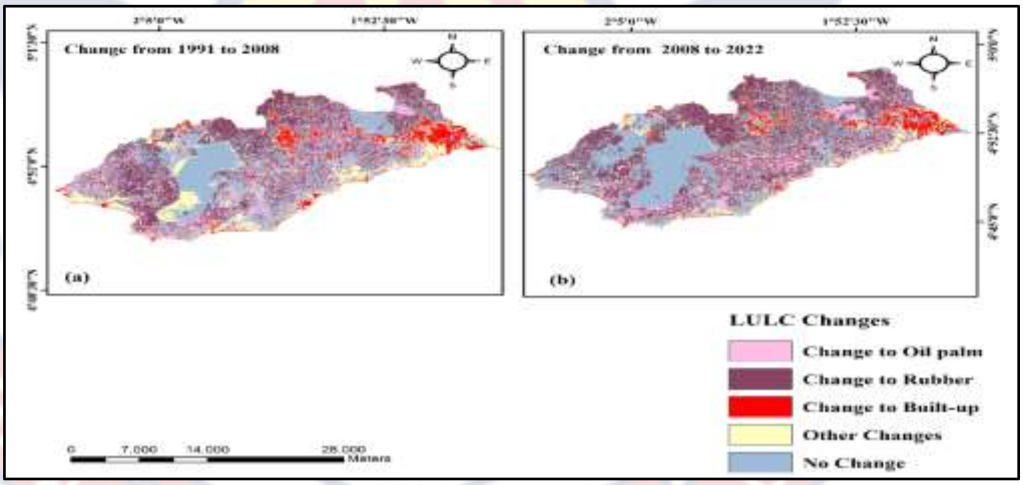


Figure 13:Change detection map of the Rainforest Agro-ecological zone from 1991to 2008 (a) and 2008 to 2022 (b)
Source: Adzigbli (2022)

Intensity Analysis of LULC Change of the Rain Forest Agro-ecological Landscape

This section presents the intensity analysis of the changes in the land cover of the Rain Forest Agro-ecological landscape from 1991 to 2022**.** The section also elaborates on the net gains and losses of the land cover categories for 1991-2008 and 2008-2022.

LULC transition matrix of the Rain Forest Agro-ecological landscape for 1991-2008, 2008-2022

The research has identified eight classification categories in the Rain Forest Agro-ecological landscape. The transition matrix was employed to illustrate the gross losses and gains indicating land transfer among the land cover categories of the Rain Forest Agro-ecological landscape (Appendix C). The persistence in the land cover accounts for 55468.62ha of the entire RFAZ (Appendix Table C1). The transition between the various land covers in the landscape between 1991 and 2008 occurred mainly in oil palm plantation (22848.48 ha) with a total gross loss of 12374.5ha, followed by croplands (6264.9 ha) and rubber (5772.51ha) forest (4599.36 ha), shrubland (3646.26 ha).

Gross Gain and Loss of Land Cover categories of the Rain Forest Agro-ecological landscape for 1991, 2008, and 2022.

The land cover categories' gross gain and loss help to escalate the pattern of changes in the Rain Forest Agro-ecological landscape. The net gains and losses support understanding the reality of the dynamics in the RFAZ. The gross gain and loss were estimated for a two-time period, 1991-2008 and 2008-2022, as presented in Table 12. In the first-time interval, shrublands(3760.47ha), oil palm(22847.94ha), and water bodies (1086.48ha) recorded a gross loss of -3257.01 ha, -2108.9 ha, and 797.76ha, respectively. The net loss in shrubland is higher than in oil palm and water bodies in the first-time interval (1991-2008). Again, rubber recorded the highest net gain of 2933.37ha compared to other LULC categories. In the second time interval, oil palm (-5561.29ha) and croplands(-5466.33ha) recorded a net loss in the landscape, while rubber had the most significant net gain of +9847.79ha in the rainforest agro-ecological zone. In the first and second-time intervals, oil palm continually increased in net gross losses from -2108.10ha to -5561.29ha, while rubber experienced a continuous increase in net gross gains from +2933.37ha to +9847.79ha in the landscape. Built-up areas also increase net gross gains from +120.33ha to +3124.71ha, respectively.

Table 12: Gross gain and loss of land cover categories of the RFAZ for 1991-2008, 2008-2022, and 1991-2022.

	Net gains/losses	
LULC Categories	1992-2008	2008-2022
Wetland	+1216.89	+1726.29
Water bodies	-797.76	+109.62
Shrubland	-3257.01	+606.42
Forest	+656.55	-4387.23
Oil Palm	-2108.9	-5561.29
Built-Up	+120.33	+3124.71
Cropland	+1236.51	-5466.33
Rubber	+2933.37	+9847.79

N.B: Net gross gain/loss area of LULC category in the current year- the area of LULC category in the previous year; negative (-) sign shows a net loss in the area extent of a LULC category while positive (+) sign shows a net gain.

Source: Adzigbli (2022)

Intensity analysis of Rain Forest Agro-ecological landscape for 1991-2008 and 2008-2022

Figure 14 shows the interval level analysis for the Rain Forest Agro-ecological landscape for two time intervals (1991-2008 and 2008-2022). The bars extending beyond the uniform annual change bar indicate that the intensity change was fast, while the bars below indicate a slow intensity change. The overall annual change of intensity (3.72%) in the Rain Forest Agro-ecological landscape during the first time was relatively slower compared to the 4.41% change in the second time interval.

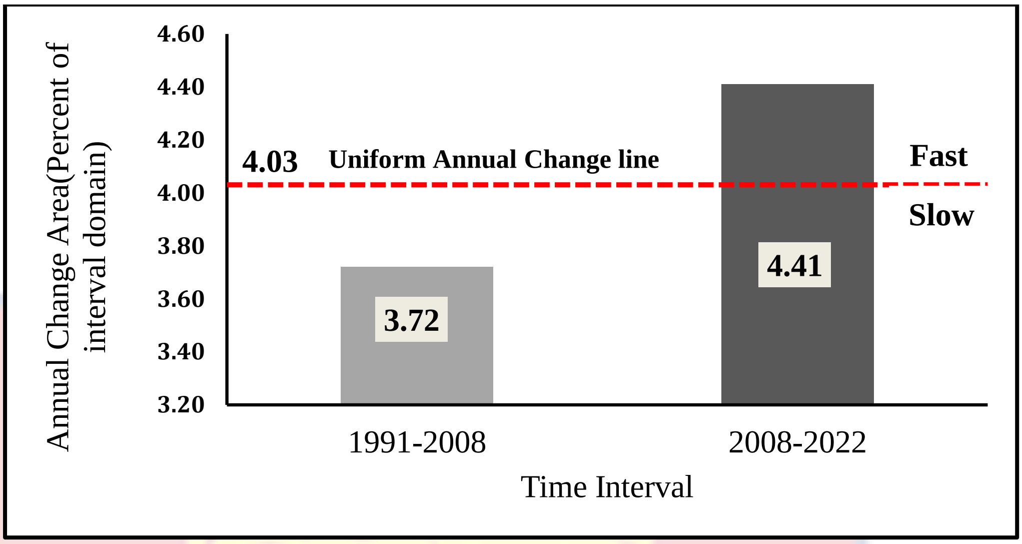


Figure 14: Interval level intensity change for 1991-2008 and 2008-2022
Source: Adzigbli (2022)

The results for category level of intensity analysis of Rain Forest Agro-ecological landscape for 1991-2008 and 2008-2022 are depicted in Figure 14. The results in the first time interval (1991-2008) indicate that oil palm plantations experienced dormant losses and gains, while Rubber plantations experienced both active gain and dormant gain. The built-up category had both active and dormant gains. In the second time interval (2008-2022), oil palm plantations recorded active losses and dormant gains in the landscape. Rubber plantations experienced active gains but dormant losses, while built-up recorded active gains and dormant losses in the RFAZ, as indicated in Figure 15.

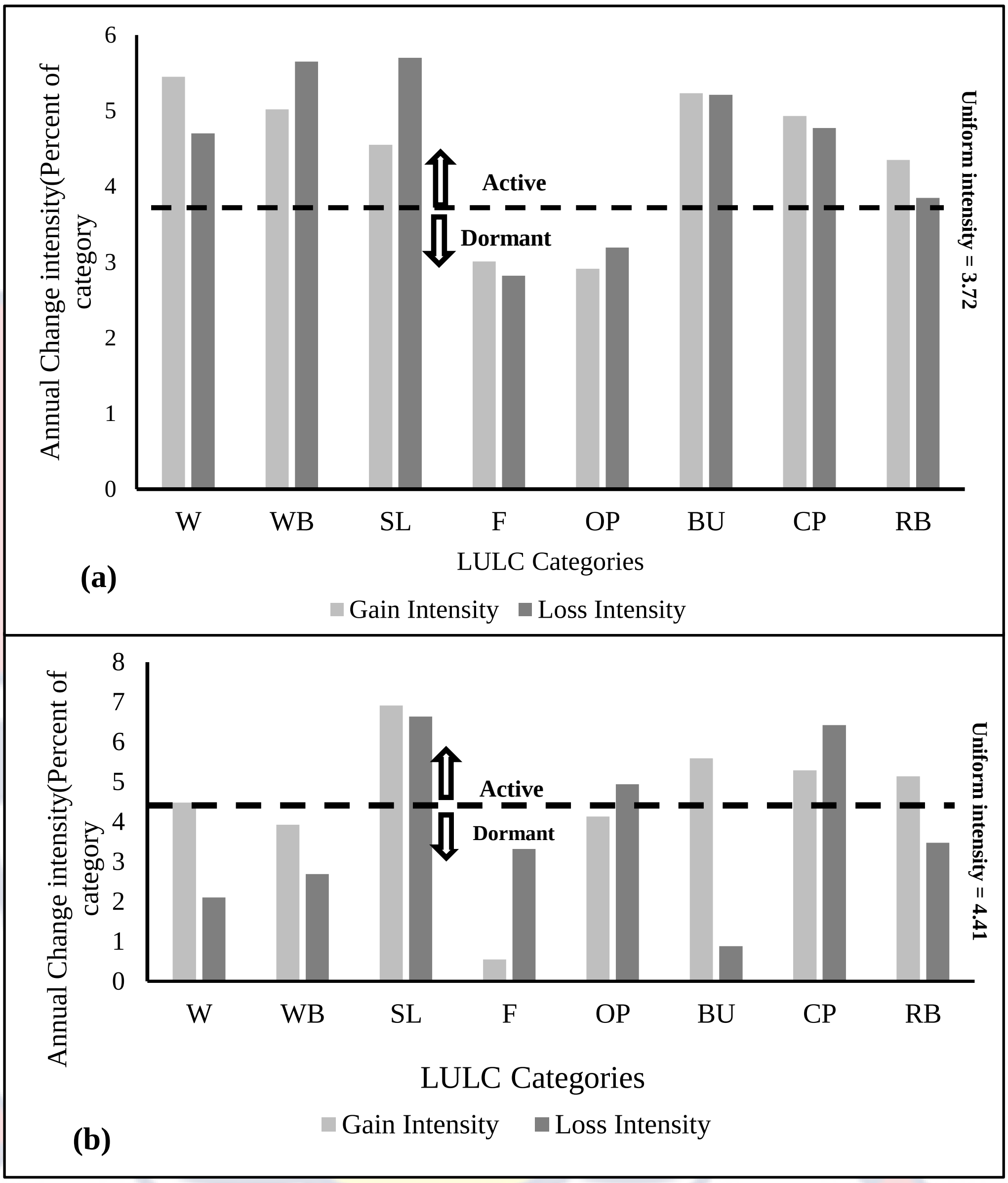


Figure 15: Categories level intensity change for (a)1991-2008 and (b)2008-2022
Source: Adzigbli (2022)

The transitional intensity in the Rain Forest Agro-ecological landscape can be identified through each category's 1991-2008 and 2008-2022 gains. The bars that project beyond the uniform intensity line target the losing LULC categories, while bars below the uniform intensity line avoid the losing categories, as indicated in Figure 16.

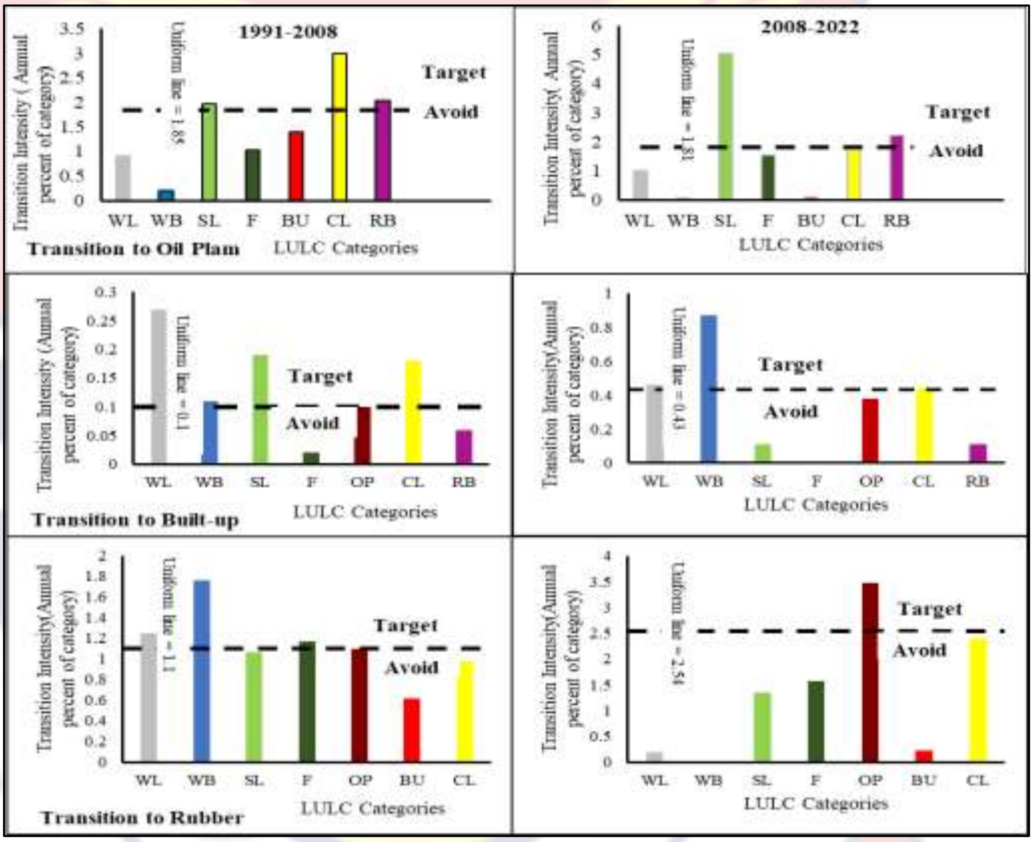


Figure 16: Transitional level intensity of the Rain Forest Agro-ecological landscape for 1991-2008 and 2008-2022
Source: Adzigbli (2022)

In the first interval, shrublands and rubber plantations were actively contributing to oil palm cover in the landscape, while water bodies and wetlands actively accounted for rubber plantation cover. The active land cover contributors to built-up environments were shrublands and croplands. Have active inputs in built-up land transition in the landscape. In the second time interval (2008-2022), rubber plantations, shrublands, and croplands were the targeted land covers contributing to oil palm plantations in the RFAZ. The oil palm is the only land cover that has contributed to rubber plantation cover in the landscape. At the same time, wetlands, water bodies, and croplands were the targeted land covers that have massively contributed to a built-up landscape environment, as shown in Figure 16.

The Implication of Agricultural-Land Use Policy on the Future Landscape

The section presents results on geospatial analysis to predict the future landscape for 2032. The section reports on the multicollinearity of the independent variables (topographic and anthropogenic factors) and simulated land cover based on the economic benefit scenario, social benefit scenario, and ecological protection in the RFAZ.

Multicollinearity of topographic and anthropogenic factors

The study used topographic and anthropogenic variables to model the land cover change. The topographic variables were elevation, slope, and aspect, while anthropogenic factors included distance to factories, settlements, farms, markets, buildings, roads, farming population, and population density (Figure 17). The variables were derived from the drivers of landscape dynamics in the RFAZ.

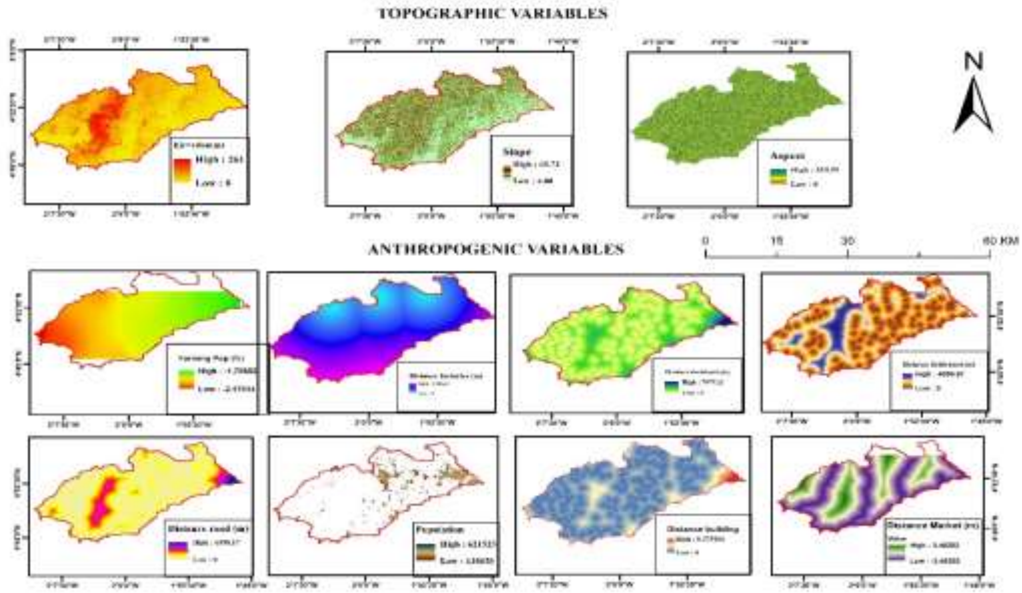


Figure 17: Map showing the spatial topographic and anthropogenic variable in the Rain Forest Agroecological zone.

Source: Adzigbli (2022)

The Maximum Variance Inflation Factor (VIF) was adopted to assess the multicollinearity of topographic and anthropogenic factors of LULC change in the RFAZ. The result in Table 13 indicated that all the variables have VIF below the 7.5 threshold, which is good for modelling the landscape. Again, distance to farm. Distance to roads and population density have a 100% significant value for the 1023 trails, with the least significant variable being the distance to settlement. Five variables (Population density, distance to road, distance to farms, distance to factories, and Aspect) produced the highest adjusted R-square value of 0.52 with Akaike's Information Criterion (680.41) Jar Bera p-value (0.10) Koenker (BP) Statistic p=value (0.00) Max Variance Inflation Factor (1.16) and minimum Spatial Autocorrelation p-value (0.00).

Table 13: Multicollinearity and importance of exploratory variables

Variables	VIF	Covariate	Sig%	Negative%	Positive%
Elevation	1.48	-	17.62	90.41	9.59
Slope	1.99	-	57.77	100	100.00
Aspect	1.48	-	88.08	100	-
Distance to factories	1.09	-	66.32	100	-
Distance to settlement	1.03	-	8.55	100	-
Distance to farm	1.18	-	100	100	-
Distance to market	1.03	-	-	81.87	18.13
Distance to building	1.03	-	56.99	0.00	100
Distance to roads	1.76	-	100	66.32	33.68
Farming population	1.05	-	25.65	88.08	11.92
Population density	1.05	-	100	100	-
Percentage of criterion passed.		Trails	Passed	%Passed	
Min Adjusted R-Square >0.50		1023	105	10.2	
Max coefficient P-value < 0.05		1023	612	59.82	
Max VIF Value < 7.5		1023	1023	100	
Min Jarque-Bera p-value> 0.10		1023	312	30.50	
Min spatial autocorrelation p = value >0.10		19	-		
Model fit		Value			
Adjusted R-Square		0.52			
Akaike's Information Criterion		680.41			
Jar Bera (BP) value		0.10			
Koenker (BP)Statistic p=value		0.00			
Max VIF Value		1.16			
Min spatial autocorrelation P-value		0.00			

Source: Adzigbli (2022)

Predicted LULC from 2022-2032 in the Rain Forest Agro-ecological Zone of Ghana

The simulation of LULC enables researchers to predict future land cover. The prediction helps to identify ecological grounds viable for the conservation of species. In this study, the Markov model was adopted to predict the future LULC of the RFAZ for ten years (2022-2032) (Figure 18).

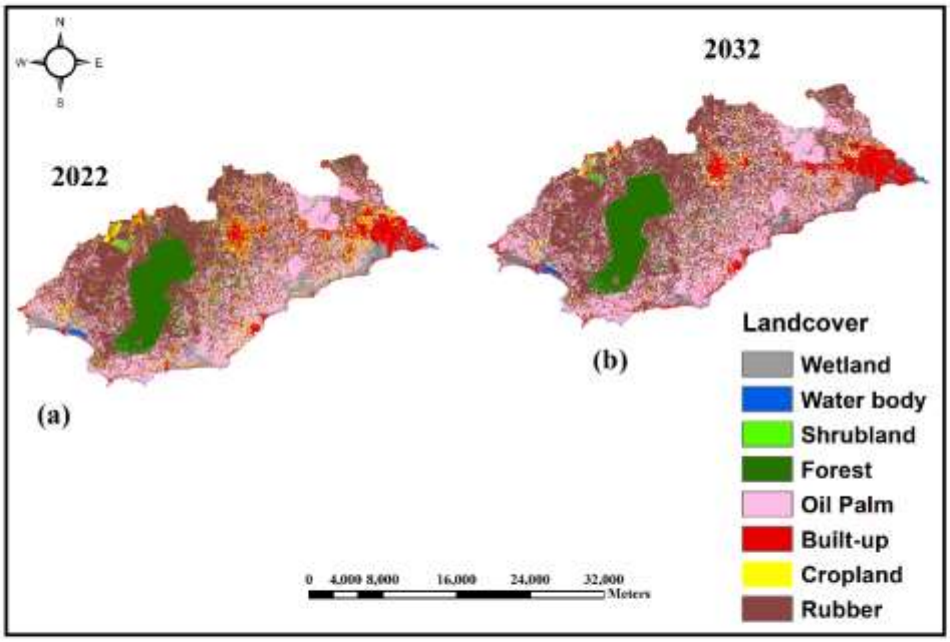


Figure 18: Predicted map of 2032 in the Rainforest Agroecological zone

Source: Adzigbli (2022)

The purpose of the simulation was to predict the expansion of cash crops (rubber and oil palm), built-up, and forest, thus the transition of other LULC categories to rubber, oil palm, built-up, and forest. The transition matrix for 2032 was computed using 2022 LULC, as presented in Table C3 (Appendix C). The probability matrix shows land categories likely to be transitioned to other classes. The model used topographic parameters such as slope, elevation, and aspect. The model also includes driver variables such as distance to water bodies, distance to factories, distance to settlement, distance to farm, distance to market, distance to the building, distance to roads, farming population, and population density. The predicted LULC for 2032 was validated using the kappa coefficient. From the validation result, the simulated map for 2032 provided a kappa component of 0.84, as presented in Figure C1.

The result in Table C3 indicated that about 39.01% of the landscape will be dominated by rubber plantations in 2032, while oil palm plantations will cover 27.30%. Forest land cover will contribute to about 10.48%, while built-ups will cover about 7.64%. Again, other LULC categories, such as wetlands, croplands, water bodies, and shrubland, will constitute 6.87%, 6.15%, 0.87%, and 0.47%, respectively. Further, the change analysis (2022-2032) indicated that rubber plantations would increase from 21611.61ha to 21640.66ha, contributing 0.05%. Oil palm plantation will decrease by -0.07% while built-ups (0.15%) will increase in 2032 from 4154.67ha to 4239.92ha. Forest reserves will decrease 2032 from 5868.27 ha to 5814.12 ha, representing -0.10%.

Analysis of Probability Transition Matrix

The transition probability matrix shows the transfer of direction of land cover categories in the RFAZ (Appendix C2). From 2022 to 2032, Rubber, oil palm water bodies, wetlands, and forests will be the most stable landcover categories with transition probabilities of 1.000, 0.9975, 0.9369, 0.9013, and 0.9243, respectively. The most dynamic categories will be built up with a transition probability of 0. 8794, croplands (0.7506) and shrublands 0.7059, respectively. Thus, built-ups that include bare lands will be transformed into croplands and rubber plantations.

Simulation of LULC under Economic benefit, social benefit, and Ecological protection scenario for the Rain Forest Agro-ecological zone

The simulation of the RFAZ land cover was under economic benefit, social benefit, and ecological benefit scenarios. The simulation predicts the future LULC for 2032 under three scenarios about agricultural policy interventions, and the outcome is presented in Figure 19.

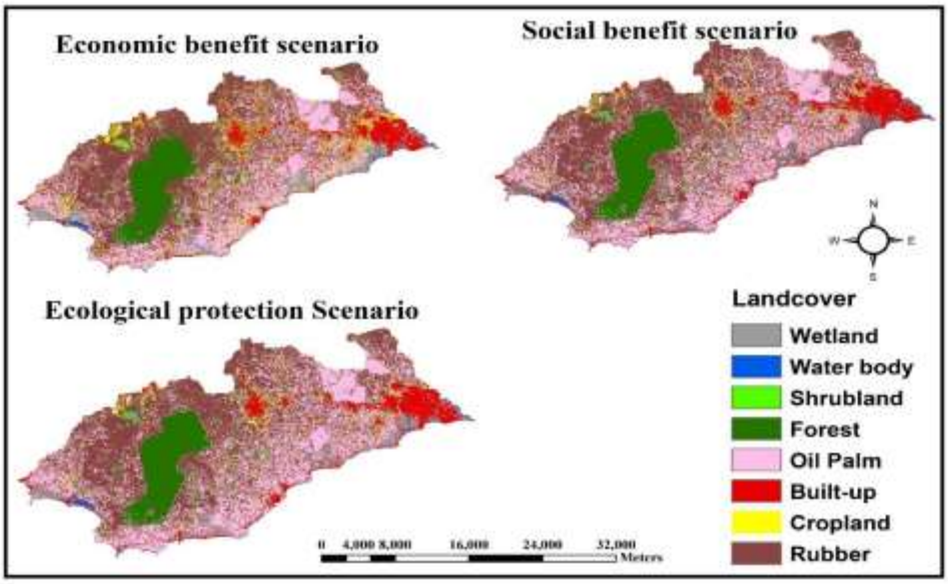


Figure 19: Map of simulated land cover under economic benefit, social benefit and ecological protection scenario in the Rain Forest Agro-ecological Zone

Source: Adzigbli (2022)

In the economic benefit scenario, rubber expansion is along the direction of market centres and major factories. The prediction has estimated that about 27.18% of the landscape will be changed to rubber expansion while oil palm and built-up will cover the landscape to about 17.23% and 11.40%, respectively. Comparing a simulated map of economic benefit scenarios for 2032 with the actual 2022 map, the conversion of other land covers to rubber plantations will dominate the landscape's western and central portions. Again, with the influence of population dynamics, high demand for lands and consistent cash crop production in the RFAZ will result in the conversion of croplands to rubber plantations, contributing to 10.17%. Further forest lands (9.56%) will be reduced under the economic benefit scenario compared to actual LULC in 2022.

The social benefit scenario is aimed at newly built areas likely to emerge in the landscape due to infrastructural development and other social interventions. According to the simulation result under the social benefit scenario, new built-up areas will expand along major road networks. New built-up lands will emerge specifically at the cash crop plantation regions in the RFAZ, contributing 14.18% to the landscape. Again, under the social benefit scenario, the land cover for built-up areas is higher than the actual LULC in 2022, and built-up areas are higher under economic benefit scenarios. The social benefit scenario outcome shows a decline in oil palm (15.52%) and rubber plantation (26.52%) land cover compared to the actual LULC. Surprisingly, there will be a significant increase in forest land cover by 12.7% in social benefit scenarios.

The ecological scenario focuses on protecting ecological areas, enhancing biodiversity and conservation. The result on the land cover under the ecological protection scenario indicates an increase in wetlands (84930.42 ha), water bodies (4488.33 ha), and forest (7757.36 ha), contributing to about 8.89%, 8.09%, and 13.99%. The simulation result further indicated a decreasing trend in rubber plantation (25.05%) cover and oil palm plantation presenting 16.83% (Table 14).

Table 24: Prediction result of LULC under Economic benefit, Social benefit, and Ecological protection scenario from 2022-2032

		LULC Categories (ha)							
Years	**Scenario design**	**Wetland**	**Water body**	**Shrubland**	**Forest**	**Oil Palm**	**Built-up**	**Cropland**	**Rubber**
	Actual LULC	3779.01	275.94	1109.88	5868.27	15177.78	4154.67	3491.46	21611.61
2022	Percent (%)	6.81	0.50	2.00	10.58	27.36	7.49	6.29	38.96
	Economic benefit	4670.15	4278.07	4622.31	5301.24	9557.18	6322.29	5641.54	15075.84
2032	Percent (%)	8.42	7.71	8.33	9.56	17.23	11.40	10.17	27.18
	Social benefit	1850.69	4167.39	5247.41	6752.21	8610.33	7864.34	6266.64	14790.65
2032	Percent (%)	3.34	7.51	9.46	12.17	15.52	14.18	11.30	26.52
	Ecological Protection	4930.42	4488.33	1948.43	7757.36	9335.40	7928.0	5183.89	13896.82
2032	Percent (%)	8.89	8.09	3.51	13.99	16.83	14.29	9.35	25.05

Source: Adzigbli (2022)

Discussion

Topographical characters of the Rain Forest Agro-ecological zone

The analysis of LULC of the Rain Forest Agro-ecological Zone indicated a change in the landscape. Topographic elements and physical features of the landscape can demonstrate these changes. According to Vongkhamho, Imaya, Yamamoto, Takenaka, and Yamamoto (2022), there is a need to consider topographical variables, thus elevation and slope establishing large-scale plantation farms. The study analyzes topographic and physical attributes of the Rain Forest Agro-ecological Zone, such as elevation, slope, aspect, distance to road, distance to water sources, and distance to buildings. The study indicated that most agricultural lands used for rubber in the Rain Forest Agro-ecological Zone have higher elevation values subjected to steep slopes. This confirms the concentration of rubber plantations in the western and south-western portions of the rainforest Agro-ecological zone. The oil palm plantations were mostly located at the east and north-eastern parts of the landscape with moderate elevation and surface slope. This finding confirmed the topography of the Rain Forest Agro-ecological Zone reported by other studies (Vongkhamho et al., 2022; Borda-Niño, Meli, & Brancalion, 2020). The steep slope nature of the landscape and high elevation clearly indicate that most farmers find it stressful planting food crops on high lands compared to low lands.

LULC Dynamics of the Rain Forest Agro-ecological Zone

The Agro-ecological rainforest landscape was primarily viewed as vegetated and non-vegetated through LULC categories between 1991-2008 and 2008-2022. Vegetated areas predominantly dominated the landscape throughout the two time intervals. This persistent dominance confirmed the study by Loh et al. (2022) that the Agro-ecological rainforest zone constituted Ghana's largest forest and vegetated areas. Unsurprisingly, the landscape was enriched with cash crop plantations and forest reserves such as the Cape Three-point Forest Reserve. The vegetated nature of the landscape could also be attributed to the double maxima rainfall patterns in the RFAZ from 1991 to 2022. This development is helpful for the cultivation of cash crop plantations and healthy forests and croplands (Loh et al., 2022). However, the changes in the landscape were better understood through the mapping and analysis of the eight LULC categories (i.e., wetlands, water bodies, shrublands, forest, oil palm, built-up, croplands and rubber) between 1991-2008 and 2008-2022.

In the second time interval, land cover changes were more intensive than LULC changes in the first interval. This implies that agricultural land use policy drivers underlying the process have increased progressively within the study periods. The drivers underpinning these processes were human-induced and linked to ROPP and NSSP policy in the RFAZ landscape. The landscape dynamics align with Ghana’s economic transformation and population growth rate since 2007 (Asante-Yeboah et al., 2022) and the discovery of Ghana’s first oil and gas in the landscape. Thus, it is unsurprising to see an expansion in the major cash crop plantations (Oil palm and rubber), which have dominated the landscape over time. A similar study conducted elsewhere confirmed that landscape dynamics in RFAZ mainly were transforming (Hen Mpoano,2019; Hackman, Gong, &Wang,2017) as represented in all the time intervals. This LULC transformation through time indicates variations in Agro-ecological landscapes in sub-Saharan Africa.

The categories and transition analysis findings of the RFAZ present information on the gains, losses, and transitions among various LULC categories. Rubber persistently expanded in the landscape in both time intervals, gaining from oil palms, shrublands, and water bodies. This implied that oil palm plantations were cleared to plant rubber plantations. Further, some LULC types in the landscape were losing to rubber and oil palm plantations. These landscape dynamics agree with the findings of Asante-Yeboah et al. (2022), who posit that Agro-ecological rainforest landscapes will be dominant with rubber, cocoanut, and oil palm in the future.

Again, the expansion in cash crops can be attributed to the collaboration between the government and private sector to boost the tree crop industry. Croplands and shrublands have experienced drastic reductions in the landscape over time. This could also be attributed to the fact that cash crops, especially rubber, fetch more income simultaneously and require fewer farm inputs than other crop types like food crops. The Built-up areas have continually increased compared to wetlands and water bodies. Forest reserves remain intact throughout the recent development in the forest. The minimal changes in the forest reserves were permitted farms under the lordship of the forestry commission.

Future Landscape dynamics under the Economic benefit scenario, social benefit scenario and Ecological protection scenario

The rapid population growth, infrastructural development and relevant agricultural land use policies could impact the LULC patterns in the RFAZ (Han, Yang, & Song, 2015). Studies have shown that government policies have influenced ecological landscapes. The simulation results indicate a dynamic change in the landscape if subjected to various projections based on conditions and assumptions. In 2032, under the economic benefit scenario, some land categories, such as shrublands and croplands, will be converted to rubber and oil palm plantations. The simulation revealed that about 45% of the landscape will be subjected to change as a result of both natural and socio-economic pressure. Comparing the 2022 map with the 2032 simulated maps under the economic benefit scenario, it was observed that rubber and oil palm plantations would expand towards the urban centres in the landscape. This implies that the land tenure systems will be largely driven by economic development such that individuals will be willing to rent lands at the urban centres for rubber and oil palm plantations. For instance, land access is a fundamental requirement under the ROPP policy; hence, farmers will be eager to trade- off other crops for rubber production in new areas while the existing areas have expanded, except areas dedicated to forest and oil palm and rubber plantation. This projection will become a reality when no spatial policies are implemented to plan and regulate built-up area growth. The landscape under the ecological protection scenario indicates that forest reserves will be maintained with emerging smaller forests. Again, under the forest protection policy, wetlands and water bodies will be expanded mostly at the coastal stretch of the landscape. The assumed landscape will become real when environmental policy and GNSDF are fully operationalized in the landscape.

Chapter conclusion

In this chapter, I have discussed the topographic characteristics of the RFAZ landscape, specifically slope, elevation and aspect. The chapter also mapped the extent of LULC categories in the RFAZ. The changes in the LULC were accessed using intensity analysis from 1991-2022. I also discussed the extent of changes in the various LULC categories. Using the Markov and S-clues model, I model and predict the future LULC in 2032 under three different scenarios. The scenarios were developed based on the drivers of landscape changes in the RFAZ. The scenarios were economic benefit scenarios, which utilized topographic and socio-economic drivers, and social benefit scenarios, which relied on population density and distance to infrastructures in the landscape. Finally, ecological protection uses distance to ecological entities like water bodies, wetlands and forest reserves.

CHAPTER SIX

EXPLAIN THE UNDERLYING FACTORS ACCOUNTING FOR THE ADOPTION OF AGRICULTURAL-LAND USE POLICIES IN THE LANDSCAPE

Introduction

This chapter presents results and discusses the factors that drive the adoption of agriculture policy in the RFAZ. The drivers were categorized into socio-economic, socio-cultural and institution/political. Socio-economic drivers in this study include crop production, marketing and trades, and urbanization. The cultural driver looks at land tenure systems, while the institution/ political driver talks about the sub-policies and regulations that regulate rubber and oil palm production in the landscape.

Crop production

The crop production in the study area has improved the landscape. Most farmers engaged in intensive cash crop production in the landscape, specifically rubber and oil palm. The rubber plantation farmers have perceived that the ROPP has increased their farm sizes compared to oil palm plantation farmers. The study also found that respondents perceived improved fertilizer application, pesticides, and higher-yielding seed breeds as contributing factors to crop production in the RFAZ (Figure 20).

Figure 20: Rubber plantation of farmers in the Rain Forest Agroecological zone.

Source: Adzigbli (2022)

The farmers in the landscape also perceived that access to credit facilities during the ROPP and NSSP enabled them to increase crop production. An in-depth interview conducted among key informants in the landscape confirmed the findings. Regarding ROPP, respondents explained that the policy has increased their crop production through training on planting and taping rubber, the application of agrochemicals such as fertilizers and pesticides, and modern technology in determining the matured rubbers for harvesting. Explaining the issues, some of the respondents have these to say;

> *I was part of the rubber out-growers plantation project the rubber estate company initiated. They used to provide seedlings and agrochemicals. They also provide an agriculture extension officer to educate us on rubber harvesting and applying fertilizers and pesticides to our farmers. After this initial by the rubber estate company, my*

production level increased, and I encountered tapping more rubber (see Figure 20). (Farmer; Male; Age= 45)

We must plant the rubber for you as part of the company policies. It takes a maximum of 7 years for the rubber to mature for tapping. With the help of our technical team, we provide farmers with hybrid seed fertilizers and pesticides in addition to tapping knives and cups, which has encouraged most farmers to increase their farm sizes to produce more rubber. (An official from Ghana Rubber Estate company).

Regarding NSSP, the farmers received inputs from the Norpalm oil company to increase palm nut production. The farmers were provided with hybrid palm nut seedlings, a collaboration between the Ahanta municipal and Norpalm oil company.

In-depth interviews with the respondents indicated that the NSSP had increased oil palm nut production, contributing to landscape change in the RFAZ. This is what some officials have to say;

The district has helped farmers with hybrid seeds and extension services to monitor their farmers. Once in a while, the community organized training workshops to educate farmers on how to control pests and diseases on their farms. Sometimes, we do this in collaboration with the Norpalm oil company with the view that the company is responsible for maintaining the activities of farmers and the NSSP policies. (An official from the district assembly).

The company has assisted the farmers during the plantation processes. The idea behind this scheme was to increase palm fruit production to feed the company so we would not be short of palm fruit. The company *has provided extension and agrochemicals to the farmer to boost crop production in the landscape* (An official from Norpalm oil company) (*Figure 21*).

Figure 21: Oil palm plantation of farmers in the Rain Forest Agroecological zone.

Source: Adzigbli (2022)

Market and trade

The market and trade drivers of landscape change in the RFAZ focus on cash crop exportation and providing raw materials to the processing companies in the landscape. The study finds that most farmers make an income from cash crops. Rubber plantation farmers had available markets for selling their rubber products. Also, Ghana Rubber Estate Company exports its dry rubber products to other end-product companies for foreign exchange. In-depth interviews with respondents revealed that farmers under the ROPP policy were willing to abandon other cash crops and focus on rubber plantations because rubber provided higher income than oil palm plantations and other cash crops. A 67-year-old farmer had this to say;

> *Previously, I used to cultivate oil palm in this community because, at that time, I did not know rubber plantations, and the income from the plantation was little compared to what l got from my oil palm plantation. The table has turned, and they enjoyed more revenue from a rubber plantation. I have destroyed 200 acres of oil palm plantation to cultivate rubber. The distance to the rubber factory has created a market for my rubber after tapping. Now, I have more than 20 poles of rubber plantation. Again, the price of a ton of rubber is three (3) times higher than oil palm and other cash crops in the landscape.*

The Norpalm oil company continues to produce in the landscape. A recent study found that the market price per ton of oil palm discouraged most farmers from cultivating oil palm. Farmers in the landscape also complained that the oil palm plantation was labour-intensive and did not generate more income than rubber. Most farmers believed higher rubber market prices contributed to the landscape change in the RFAZ. Thus, farmers are now planting their nursing and buying their tapping tools. The trade between the farmers and the cash crop companies was profitable, especially for rubber. Thus, the availability of an already existing market for rubber products has also accounted for the rapid increase in farm sizes by some farmers in the landscape to accumulate more income. An in-depth interview with officials from the district assembly indicated that rubber plantations had dominated the land because another cash crop had failed to increase the unit price of their commodities to much higher than the unit price of rubber. One official had this to say;

> *Previously, oil palm and coconut used to be the dominant land cover in the landscape because the price of oil palm was high then. In recent times, rubber companies have lucrative packages such as providing access to credit for farmers and buying them out at a higher price. An income from rubber is sustainable compared to other cash crops. This development has pushed the majority of farmers into the rubber plantation*. (An official from the district assembly)

Urbanization

The study also revealed that urbanization has contributed to landscape land cover change. An in-depth interview indicated that the population increase in the landscape was attributed to the rubber plantation and the discovery of oil and gas at the cape point of the landscape. The landscape has seen development in the build-up areas, especially the emergence of new oil companies and other infrastructure.

> *The landscape has recently changed due to our district's discovery of oil and gas. The population has also increased predominantly since the discovery; again, most of the farmers in the rubber plantation have gained more knowledge in rubber planting; hence, more people have trooped into the landscape to learn about the planting.* (An official from the district assembly)

Land tenure

The study identified that the land turner system practices among the people in the landscape were abused. It was easy to lease land and even strangers to indulge in runner farming. The ROPP and NSSP essential requirement for inclusion in the policies was access to land for cultivation. Table 15 indicates the type of cash crop cultivated and land access among farmers in the landscape. The study shows that out of 112 rubber farmers interviewed, the majority (62.5%) own their farms, while 17.38% (rented), family (8.03%), private (6.25%), and 5.35% were accessed through friends. Of the 56 oil palm farmers engaged in the landscape, most lands (71.42%) were self-owned, 16.07% were rented, and 7.14% were family lands. Further, 3.57% were friends' lands, while private lands contributed 1.78% respectively. The study also indicated that farmers were willing to rent lands for their plantations even if they did not own them.

Table 15: Type of cash crop cultivated and land access among farmers

	Access to farmland					
Type of cash crops cultivated.	Self (%)	Rented (%)	Family (%)	Friend (%)	Private (%)	Total (%)
Rubber	62.50	17.85	8.03	5.35	6.25	100
Oil palm	71.42	16.07	7.14	3.57	1.78	100

Source: Adzigbli (2022)

An in-depth interview conducted among some farmers in the landscape revealed that access to land has become very tricky in recent times because individuals prefer to rent out lands for rubber plantations. This has contributed to a persistent rise in rubber plantations as a driver for landscape changes in the RFAZ. One farmer interviewed had this to say;

I have eight (8) poles of rubber plantation in this community. I am a stranger in this community, but I was able to rent land to cultivate rubber. There is much money in rubber compared to oil palm and

> *other cash crops. At the end of the harvesting period, I divided the output into parts of which my land owner was eligible for one portion of the total production* (Rubber farmer; Male; Age=52).

Political/institutional drivers

The political drivers in the context of this study refer to institutional policies towards cash crop production and land use planning in the RFAZ. The study found that ROPP has no procedure for conservation and land management. The ROPP instead paid attention to profit maximization and production. The NSSP has a conservation policy that drives changes in land cover in the landscape. The High Conservation Values Areas policy of the NSSP is committed to identifying places in the landscape and implementing adequate strategies to manage and protect them. Some of the strategies include no clearing beyond 60 meters along water bodies with a width of more than 20 meters, and for perennial rivers with a width of fewer than 20 meters but greater than 5 meters in width, 20 meters will be restricted as a buffer. The strategy noted that no replanting and development activities on a slope greater than the existing crop and vegetation shall be maintained. An official from the Norpalm oil company had this to say;

> *The company has policies that target the conservation of the landscape. Even though we are a profit-making organisation focusing on production, we also care about the physical environment and how to improve biodiversity*. (see *Figure 22*) (An official from Norpalm Oil Company).

Figure 192: Conservation area under NSSP policy in the rainforest agroecological zone of Ghana

Source: Adzigbli (2022)

Discussion

The LULC is a complex phenomenon that directly or indirectly influences landscape dynamics through driving forces operating on different scales. An interview among various stakeholders and farmers revealed that drivers of the LULC change in the RFAZ concerning agricultural policies were attributed to crop production, Market and trade, population dynamics, land tenure and access to credit. Among these driving forces, population growth and crop production were acknowledged as the main forces behind the changing landscape dynamic. The population growth is in line with Ghana's economic transformation since 2007 (Diao, Hazell, Kolavalli, & Resnick, 2019; Tahiru, Doke, & Baatuuwie, 2020). In 1991, before the agricultural-land use policies, and in 2022, after the policies were operationalized in the landscape. Again, due to population growth in RFAZ, farmers were forced to cultivate cash crops on steep slopes and marginal lands, which are not recommended for sustainable agricultural practices. The practices result in changes in the landscape, specifically in rubber and oil palm-dominated communities. The result was consistent with the findings of (Diao et al., 2019), which explained that population dynamics affect LULC through the cultivation of crops in marginal lands. The crop production driver in the landscape was influenced by ROPP and NSSP, such that most farmers accepted the policies that have improved their livelihood. Hence, it pushed farmers in the landscape to invest their resources in crop production. The availability of an already existing market for rubber and oil palm bunches has influenced most farmers to get involved in cash crop cultivation.

In the landscape, the partnership agreement between the cash crop processing companies (GREL and Norpalm) created a high demand for cash crops (Rubber and oil palm). This has compelled most farmers to cultivate more cash crops despite the company's plantation farms. Access to land for cash cultivation has also contributed to LULC in the landscape, such that they were willing to use the small available lands for plantation purposes. This is a common practice because of the ‘profit', especially in rubber plantations. Again, individual landowners were willing to lease any land intended to be utilized for rubber or oil palm production. Farmers ' access to credit facilities through agricultural policies has contributed to LULC changes in the RFAZ. The credit facilities in terms of allowances and money for keeping their farms have encouraged most farmers to be involved in cash crop plantations. The pre-finance option available to farmers has enabled farmers who cannot invest in cash crop cultivation to have the opportunity to get involved through contract agreements and payment plans. This finding supported the study by

(Ankrah-Twumasi et al., 2020), which points out that credit availability to support farming expands farm sizes and the acquisition of additional lands.

Chapter conclusion

The chapter pointed out the drivers of landscape dynamics in the RFAZ. The study highlighted the drivers in four main categories: socio-economic, cultural and institutional/political. The socio-economic drivers include crop production, market and trade, and urbanization, while cultural drivers examine land tenure systems. The institutional/political driver highlights sub-policies contributing to the RFAZ's landscape changes.

CHAPTER SEVEN

ASSESS THE EFFECTS OF LANDSCAPE DYNAMICS ON FOOD SECURITY AND HUMAN WELL-BEING (AS THEY RELATE TO SUSTAINABLE DEVELOPMENT GOALS)

Introduction

This chapter presents the effect of landscape dynamics on food security and human well-being. I discuss the implication of landscape dynamics on food security under the rubber outgrower plantation project (ROPP) and the Norpalm Smallholder Scheme Project (NSSP). The chapter also looked at the implication of landscape changes on human well-being under ROPP and NSSP.

Landscape dynamics; implication for food security/insecurity and human wellbeing under rubber Outgrower plantation Project.

The cropland (1236.51 ha) had the highest transiting land cover during the first-time interval (1991-2008), above the uniform line of 1.85 (Figure 16). In the second time interval, oil palm (-5561.29 ha) and croplands (-5466.33 ha) lost to other LULC categories in the landscape, contributing to a total change of -5466.33 ha (-9.85%). The result from the study shows that GEP and GNSDF contribute to food security by providing environmental and spatial guidelines that contribute to sustainable agriculture. The ROPP and NSSP do not consider food security in the landscape, even though they aim to provide sustainable livelihood to smallholder farmers. The study found that both ROPP and NSSP were interested in generating raw materials for industrial purposes in the landscape rather than cultivating food crops. An in-depth interview with key informants revealed that the farmers are more concerned with cultivating cash crops than food crops. He had this to say;

> *As a district, we know the implication of cash crop production on food security. Even though we encouraged farmers to diversify their crop production, most farmers were delighted in cultivating rubber and other cash crops rather than food crops. As a district, we do not control the activities of cash crop farmers in the landscape, but we just come as mediators if the need arises. The competition for land is between industries and agriculture. We cannot stop the growth of cash crop plantations, specifically rubber, because that industry is becoming more lucrative.* (An official from the agriculture unit of the Ahanta West district assembly)

The study also found that though rubber posed a high risk to food security, cash crop actors viewed the situation otherwise. The management of the cash crop plantations comments that they have provided a livelihood for numerous smallholder farmers in the landscape, improving their well-being in the long run. An interview with an official from a rubber estate company had this to say;

> *The rate at which people are going in for rubber plantation is alarming in these areas. As an organization, we care about the livelihood of our farmers in the landscape and want a sustainable livelihood that will improve their general well-being. Hence, we encourage them to leave some of their plots for food crop cultivation*
>
> (An official from the Rubber Easter company).

Further, the study showed that farmers have been experiencing a hike in the cost of food crops compared to thirty (30) years ago. One chief farmer had this to say;

> *Food crops are indeed costly compared to 30 years ago. In the past, we did not know about a rubber plantation. We focus on oil palm and coconut plantations where we can plant food crops together with these cash crops. Due to the income I get from the rubber, I used all my plots for rubber plantation. Food crops such as cassava and plantain are very expensive in this area.* (Farmer; Male; Age=47)

The ROPP and NSSP seek to improve farmers' wellbeing by accomplishing their collective social responsibilities by providing basic amenities in the landscape.

Discussion

The dynamics of the RFAZ landscape has implications for food security induced by a significant transition of croplands to rubber plantation in the landscape for rubber production. In sub–Saharan Africa, agriculture drives the economy of many countries; hence, any loss of agricultural land poses a threat to food production (Ofori, Cobbina, & Obiri, 2021). In the first-time interval (1991-2008), croplands have gained about 1236.51 ha of land in the landscape. It indicates that most farmers then were practising intercropping agriculture systems for oil palm production. Consequently, the shrinkage rate of croplands rapidly increased in the second time interval (2008-2022), contributing to a total loss of 5466.33 ha. The shrinkage of croplands in the landscape resulted from the industrial establishment and rise in rubber production, which decreased arable croplands for food production in the RFAZ. Hence, it was predicted that the depletion of croplands in the RFAZ in 2032 will lead to the progressive domination of cash crops, mainly rubber and oil palm plantations, in the face of urbanization. Comparison between the

ROPP and NSSP indicates that food crop production was higher in the NSSP than in the ROPP. The stable income influenced the decision rubber farmers enjoyed from rubber cultivation and the availability of credit facilities in the form of loans to support their farms in the long long-run crippled race of achieving the sustainable goal 2. Though ROPP provides a lucrative incentive to encourage rubber production in the landscape, it also causes alarm for the high risk of food insecurity if not addressed in the coming days.

Regarding well-being, the study found that farmers in the landscape derived satisfaction in infrastructure development, which improved their well-being. The land dynamic under the agricultural-land use policies has improved the socio-economic dimension of farmers' lives. In this study, well-being is expressed through satisfaction of livelihood and infrastructural development like roads, schools, hospitals and other basic amenities. The study pointed out that smallholder farmers enjoy higher income from rubber plantations than from oil palm plantations. The income has improved their well-being, especially those involved in rubber cultivation.

Further, farmers diversify their income to various projects and businesses, which has improved their savings capabilities. Regarding sanitation, most respondents agree that the ROPP and NSS have tackled sanitation issues by providing sanitation facilities in some of the communities as part of their corporate social responsibility. This implies that the provision of social amenities is not mandated only to the government, but policy actors could also assist in fulfilling this mandate. Concerning health, the changes in the landscape through agricultural-land use policies could improve the health status of the respondents in the study area if health facilities were adequately provided in the landscape. The study found that ROPP policies have provided health facilities. For instance, GREL has constructed health centres (clinics) in some major rubber production communities in the RFAZ. Again, the ROPP has enabled educational facilities in the landscape. The educational facilities promote quality education in the landscape, promoting the race to achieve the United Nations Agenda 2030 for Sustainable Development Goal 4.

Further, the rehabilitation of feeder roads by GREL under the ROPP improves transportation networks in the rubber-growing communities. As affirmed in Alhassan (2021), transportation is an important element for boosting the agricultural economy in Sub-Saharan Africa. Transportation networks help transport cash crops from the farm gate to industries for processing in the landscape. Therefore, the reduction of croplands due to the implementation of ROPP and NSSP would negatively impact the achievement of food security. Hence, using these croplands not for food crop production but to expand industrialization would contribute to food insecurity in the RFAZ landscape of Ghana.

Conclusion

In this chapter, I have argued that ROPP and NSSP could affect food security and human well-being. I argued the complex nexus between landscape dynamics, food security and human well-being. The chapter concludes that rubber cultivation under the ROPP could affect food security if not regulated and managed on the landscape.

CHAPTER EIGHT

SUMMARY, CONCLUSION AND RECOMMENDATION

Introduction

This chapter presents the summary of the study, which focuses on agricultural land use policies and landscape dynamics in the RFAZ of Ghana. The chapter highlights the study objectives, methodology and the major findings. Chapter eight also provides conclusions based on the objectives established in the study. Finally, the chapter presents recommendations and suggestions that could help address the key issues and gaps identified from the study.

Summary of Study

The study was informed by knowledge gaps exploring agricultural-land use policies and landscape dynamics in the Agro-ecological zone in Ghana and sub-Saharan Africa. The study focused on exploring agricultural land use policies and landscape dynamics in the RFAZ of Ghana. The specific objectives were as follows;

- Analyse the application of agricultural land use policies in the RFAZ.
- Examine the impact of agricultural land use policies on the landscape of the RFAZ from 1991 to 2022.
- Explain the underlying factors accounting for adopting agricultural land use policies in the landscape.
- Assess the effects of landscape dynamics on food security and Human Well-being (as they relate to the Sustainable Development Goals)

The study covered eight chapters, with the first chapter focusing on the introduction by providing the need for conducting the study. It gives an account of the whole study by providing the problem and the study's objectives. Chapter Two reviewed relevant literature on landscape dynamics and agricultural policies, while Chapter Three highlighted the methodology involving the philosophical foundation underpinning the study. The chapter also presents the research design and approach, sampling procedures, and analytical tools adopted to explore the field data. Chapters four, five, six, and seven focused on findings and discussions based on the study's objectives. Chapter eight presents the summary, conclusion and recommendations.

The study employed a mixed-method research approach involving quantitative and qualitative research methods. The study population comprised two categories of people: cash crop farmers and key informants. 192 cash crop farmers who have been in cash crop farming for at least ten years were selected from six communities (Abura, Egyambra, Akwidaa, Sankor, Domeabra and Apowa) for the structured interviews. The key informants include reps from the Ministry of Agriculture, Land Use and Spatial Planning Authority (LUSPA), Forestry Commission Ghana, Rubber Estates Limited (GREL), Norpalm Company Limited and some farmers with in-depth knowledge of the landscape of the RFAZ for the in-depth interviews. The study used expert knowledge to select study communities, while purposive sampling was adopted to select the key informants. The cash crop farmers were selected through a random probability sampling technique. The study relied on both primary and secondary data. The Sprimary data includes structured and in-depth interviews, while secondary data relied on satellite images, policy documents, articles and reports.

Major Research Findings

The policy review under the production pillar of the RFAZ landscape revealed that ROPP, NSSP, and GEP satisfied all three elements (sustainable production, land management and production systems) except GNSDF, which considers only land management elements. Again, regarding the conservation pillar, NSSP and GEP consider all the conservation elements (Biodiversity, Natural resource management and ecosystem services). The GNSDF only considers natural resource management elements, while ROPP does not consider any conservation elements in their policy. Further, the policy review on the livelihood pillar acknowledged that all the policies (ROPP, NSSP GEP and GNSDF) considered infrastructural development and wellbeing elements in the RFAZ. Furthermore, ROPP NSSP did not consider the human settlement element in their policy.

The impact of ROPP on the landscape revealed that agricultural inputs, including fertilizers, pesticides, higher-yielding seedling breeds and access to credits, influenced landscape change in the RFAZ. The benefits (training in modern agricultural technology, increased farm sizes, cultivation of more crops) farmers gained from ROPP and NSSP have statistically contributed to landscape change. Under both ROPP and NSSP, access to land was a major contributor to landscape change.

The study's findings also revealed that the RFAZ was dominated by the oil palm LULC category in 1991 but declined continually from 2008 to 2022, paving the way for the rubber LULC category to increase within the second time interval. The increase in the rubber LULC category was influenced by crop production, market and trade, urbanization, land tenure system and institutional policies in the RFAZ. Regarding crop production, farmers were provided with agricultural inputs such as agrochemicals and credit facilities.

The annual rate change in the first-time interval was relatively slower compared to the second-time interval, whereas in the second-time interval, the annual change was relatively faster compared to the first-time interval. The annual rate of change for oil palm plantations was higher during the first time interval but slower at the second time interval. Rubber and built-up annual change were higher in the second time interval.

The simulated LULC map for 2032 under economic benefit scenarios reveals that rubber plantation (6322.29 ha) and oil palm plantation (5641.54 a) will contribute to about 44.41% of the landscape in the RFAZ. The social benefit built-up (7864.34 ha) was projected to cover about 14.18% of the landscape. The forest reserves, wetlands and water bodies will constitute about 30.97% of the ecological protection scenario in 2032.

The study found that the existing market for rubber products has massively contributed to an increase in rubber plantation than oil palm among farmers in the landscape. The income accumulated from rubber is sustainable compared to that of oil palm. However, the study identified that individual farmers owned the majority of the lands in the landscape while some were rented and family lands.

The finding shows that ROPP and NSSP policies do not consider food security in the landscape, even though they target improving the livelihood of farmers. The study found that food security would be under threat in the RFAZ landscape as farmers continue to cultivate cash crops.

Conclusion

- The review and assessment of agricultural land use policies have helped to identify agriculture elements lagging in the various policies (ROPP, NSSP, GEP and GNSDF), which could help improve sustainable agriculture, planning and landscape management. The impact of the policies on the landscape would be an eye open to policymakers to realign many interventions toward sustainable land management in the long run to strengthen production systems, conservation human systems and institutions.
- The application of geospatial analysis to model the RFAZ has helped monitor the landscape changes from 1991 to 2022. The LULC changes in landscape were mainly influenced by ROPP and NSSP. Though topographic drivers have influenced the landscape, their impact was not higher than the anthropogenic factor in which ROPP and NSSP play a major role in landscape change. The simulated LULC based on economic benefit, social benefit and ecological protection scenarios in the landscape might not occur in the short run. However, maps that forecast the potential future developments on the landscape can be used as a benchmark for communicating spatial development policies to diverse stakeholders that manage the resources on the landscape.
- The factors that drive the adoption of agricultural policies in the landscape will educate stakeholders on farmers' decision to accept agriculture interventions. It will also assist in land use planning and management by regulating specific drivers in the agricultural land use policies that cause landscape changes in the RFAZ.

- The loss of arable croplands to rubber and oil palm plantations constitutes a high risk of food insecurity in the landscape and decreases the resilience of the rural population.

Recommendation

Based on the findings of this study, the following recommendations are suggested to sustain the RFAZ.

1. The Ahanta West district assembly, Ministry of Food and Agriculture and NGOs should engage the GREL and Norpalm companies to revise sub-policies that could affect landscape change. The GREL and Norpalm companies should allow Ahanta West's food and agriculture department to regulate the activities of the farmers in the landscape.
2. Efforts should be channelled toward raising public awareness concerning landscape management by fostering knowledge through environmental education. This should be done through the Forestry Commission in collaboration with the Land Use and Spatial Planning Authority.
3. The Environmental Protection Agency and Forestry Commission should engage the Ghana Rubber Estate Company (GREL) and Norpalm Oil Company on conservation plans towards the sustainability of the RFAZ. It will help refine policies and practices that are more environmentally responsible among these institutions in the landscape.
4. There should be an initiative to minimize the trade-off in land use decision-making among farmers regarding rubber plantation. This should be done in collaboration with the Ministry of Food and

Agriculture in the district assemblies and other stakeholders in the landscape to improve food crop production and rural livelihood adequately.

The study could not address some crucial issues in the RFAZ that need urgent attention. Thus, further research was recommended to address the following issues;

1. The loan repayment arrangement among Rubber Outgrowers Plantation members.
2. A comprehensive approach to assess the activities of cash crop farmers in the RFAZ.
3. Adapt high-resolution satellite images that separate LULC categories such as oil palm, rubber and coconut plantations.

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APPENDICES

APPENDIX: A1- STRUCTED INTERVIEW AND INTERVIEW GUIDE

UNIVERSITY OF CAPE COAST
FACULTY OF SOCIAL SCIENCE
DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING
QUESTIONNAIRE

SECTION A: Introduction

Community Name: GPS Coordinate

Dear respondent,

This research aims to model the effect of **agricultural-land use polices and landscape dynamics in the Rain Forest Agro-ecological Zone of Ghana** from the cash crop farmers perspective and also understands various landcover changes associated with agricultural land use policies. The questionnaire focuses on the dimension of land cover, farmers directive on agricultural-land use police and landscape dynamics. There are no financial or direct personal benefits from taking part in this research; however, the results are likely to be of use by local authorities, community groups, civil society organisations, and international bodies in taking further required actions regarding landscape management. The research will reserve your right of anonymous participation and treat your information completely confidentially. Your information will be used solely for academic purposes. I believe this take about 45 minutes- 60 minutes of your time. Your co-operation plays a key role in the successful completion of this study and will be highly appreciated. If you have any reservations about this survey, please feel free to contact

Wonder Kofi Adzigbli on 0248667117 or email to wonder.adzigbli@stu.ucc.edu.gh .Thank you.

SECTION B: Demography characteristics of respondents

1. Sex. A. Male [ ] B. Female [ ]
2. Age ……….
3. Education level. No formal education [ ] Basic [ ] Secondary [ ] Tertiary[ ]
4. Religion. Christian [ ] Muslim [ ] Traditional [ ] other [ ]
5. Marital Status of respondents. Single [ ] Married [ ] Divorce/separated [ ] Widow(er) [ ] Other……………..
6. Number of households Size……………….
7. What is your monthly income at the end of the farming season ……….
8. Are you a member of any cash crop farmer's association? Yes [ ] No [ ]
9. If Yes, Specify……………………….
10. Does any of your household own a farm in Rainforest agro-ecological zone? Yes [ ] No [ ]
11. If Yes, type of access or Ownership? Rented [ ] Family[ ] Friend [ ] Private [ ] Government [ ] Other (Specify)……
12. Main type of cash crops grown during this year's farming season? Rubber [ ] Oil Palm [ ] Cocoa [ ] Other [ ]
13. Who is responsible for managing your farm? Husband [ ] wife [ ] children[ ] Non family member [ ] Other [ ]
14. Which of the crops have you continually cultivated in the past 10years? (**Tick as apply**) Rubber [ ] Oil Palm [ ] Cocoa [ ] Other [ ]
15. Quantity output of Rubber (tonnes)……………
16. Quantity output of Oil Palm (in tonnes)……………
17. Quantity output of Cocoa (per bag)………………
18. Quantity output of other crops (in sack)…………..
19. Years of experience in cash crop farming? …………….
20. Size of your Cash crop farm (Hectares)…………………
21. What is the distance from road to your farm (Metres)…………………

22. What is the distance from building/settlement to your farm (Metres)……………
23. What is the distance from water source to your farm (Metres)……………
24. What challenges did you experience during cash crop (Rubber, oil palm , cocoa) farming?..

SECTION C: THE RATE OF CHANGE OF THE RAIN FOREST AGRO-ECOLOGICAL ZONE LAND COVER

25. Do you think the land cover in Rain Forest Agro-ecological Zone is changing? Yes [ ] No [ ]
26. Which of the following land covers is increasing the most? Wetland [ ] water bodies [ ] Shrublands [ ] Forest [ ] Oil Palm[ ] Built-up [ ] cropland [ ] Rubber [ ]
27. What is the rate of increase of the fastest increasing land cover? High [ ] Moderate [ ] Low [ ]
28. Which of the following land cover is decreasing the most? Wetland [ ] water bodies [ ] Shrublands [ ] Forest [ ] Oil Palm[ ] Built-up [ ] cropland [ ] Rubber [ ]
29. What is the rate of decrease of the fastest decreasing land cover? High [ ] Moderate [ ] Low [ ]
30. How will you rate your level of acceptability of land cover change in the Rainforest agro-ecological zone? None [ ] Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]

SECTION D: IMPLICATIONS OF AGRICULTURAL-LAND USE POLICIES ON LANDSCAPE DYNAMICS

31. Who owns the biggest responsibility to check the land cover change in this area? (**Tick as apply**) Government [ ] Physical Planners [ ] Forestry commission [ ] Agric extension officers [ ] Farmers [ ]
32. Beyond you who are the major contributors to land cover change in the rainforest agro-ecological zone? Farmers [ ] Building contractors [ ] Government [ ] Private companies [ ] Other (specify)………
33. Which of the land covers in the Rain Forest Agro-ecological Zone do you predict in the future (Tick **as apply)** Wetland [ ] water bodies [ ] Shrublands [ ] Forest [ ] Oil Palm[ ] Built-up [ ] cropland [ ] Rubber [ ]
34. How often are the issues of land cover change discussed with local authorities? Low [ ] Moderately [ ] High [ ]
35. Please evaluate accelerated agricultural modernization, sustainable natural land management, infrastructural and human settlement and livelihood under the various agricultural-land use policies of the rainforest agro-ecological zone. Indicate to what extent do you agree to the following statement (1 being the least effect and 5 being the highest effect).

Policies	**Rubber Outgrowers Plantation Project (ROPP)**	**Norpalm Smallholder Scheme Project (NSSP)**
I have been able to cultivate more cash crops than previous years.	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
My quantity of cash crops has increased after the policies ended	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
I have been trained on post-harvest loses techniques	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has enabled me to apply the right proportion of fertilizer	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High

		[ ]
The policy has enabled me to apply the right proportion of pesticides	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
I have acquired higher yielding seedling breeds	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has helped me to get access to credit.	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The polices have made me to change my farming pattern on the land	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
I have acquired training in modernize agriculture technology	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has changed my farm size	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy helps to manage Forest and other natural resources overtime	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The soil fertility in my farm has improve	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy help to provide ecosystem services in the landscape	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy help to improve biodiversity (e.g., rivers/streams).	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
New roads have been constructed and rehabilitated in this community	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
New hospitals facilities have been constructed and renovated in this community	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]

Water and sanitation have been improved in this community	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has helped in planning the building patterns in the community	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
There is growth in new buildings	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has changed the spatial pattern of the landscape as compared to 30years ago	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has increased my livelihood	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has improved my wellbeing	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
The policy has improved my monthly income	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
I have enough access to land.	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]
I have good relations with other farmers	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]	Very Low [ ] Low [ ] Moderately [ ] High [ ] Very High [ ]

36. What challenges did you experienced during the implementation of FASDEP I &II policy in the rainforest agro-ecological zone?.......................................
37. What challenges did you experienced during the implementation of Agriculture Service sector Investment Program (AgSSIP**)** in the rainforest agro-ecological zone?...
38. What challenges did you experienced during the implementation of Planting for export and rural development in the rainforest agro-ecological zone?...

39. What challenges did you experienced during the implementation of Land registration and digitization program in the rainforest agro-ecological zone**?..**

Appendix: A2

UNIVERSITY OF CAPE COAST

FACULTY OF SOCIAL SCIENCE

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

INTERVIEW GUIDE FOR PRIVATE CASH CROP PLANTATION INSTITUTIONS

Dear respondent,

This research aims to model the effect of **agricultural-land use polices and landscape dynamics in the Rain Forest Agro-ecological Zone of Ghana** from the crop farmers perspective and also understands various landcover changes associated with agricultural land use policies. The interview guide focusses on agricultural policies and land cover changes. There are no financial or direct personal benefits from taking part in this research; however, the results are likely to be of use by local authorities, community groups, civil society organisations, and international bodies in taking further required actions regarding landscape management. The research will reserve your right of anonymous participation and treat your information completely confidentially. Your information will be used solely for academic purposes. I believe this take about 60 minutes- 90 minutes of your time. Your co-operation plays a key role in completing this study and will be highly appreciated. Thank you.

Details

Date of interview: Position of interviewer:

Number of participants: Place for interview:

Age of interviewer Sex of interviewer:

What other occupation does the interviewer engage in and why?

AGRICULTURAL-LANDUSE POLICIES AND LANDSCAPE CHANGES

1. What agricultural policies/projects/intervention have your institution implemented for cash crop farmers in your company or area?
2. How does these policies/projects/interventions influence the activities of cash crop farmers in your institution?
3. What roles do your institution perform in regulating the activities of cash crop farmers in the rainforest agro-ecological zone? Comment on the where you draw your source of authority from.
4. How does your institution or organisation perform these roles and which one(s) does your institution perform best?
5. In general, how do you see your policies/projects/interventions changing the landscape in the Rain Forest Agro-ecological Zone over the years?
6. How do you see the agricultural policies and land use planning regulations of Ghana on the management of cash crops (specifically rubber, oil palm, cocoa)? Comments on implementation and enforcement of such policies, regulations, and laws.
7. What challenges does your institution face in implementing these policies/projects/interventions in the Rain Forest Agro-ecological Zone over the years?
8. What is the level of collaboration between your company and other the authorities mandated to plan and manage the Rain Forest Agro-ecological landscape ? Probe for specific bodies.

IMPLICATIONS OF AGRICULTURAL POLICIES ON LAND USE/ LAND USE LANDCOVER

9. What is the nature of the management plan and conservation strategies for the cash crop Plantation Site? Comment on the management measures and their implementation, institutional arrangement for management, long term management objectives, and action plans.
10. Comments on the factors influencing the attainment of the said objectives and the implementation of the action plans?
11. How does your policies/projects/intervention improve the agricultural modernization in the area?
12. How does the company's policies/projects/intervention improve natural resource management?
13. How does your policies/projects/intervention improve Infrastructure on the rainforest agro-ecological zone?
14. How does your policies/projects/interventions improve the livelihood of farmers in your company?
15. What is your general view on the status of the rainforest ago-ecological landscape. Comment on new?

Appendix: A3

UNIVERSITY OF CAPE COAST

FACULTY OF SOCIAL SCIENCE

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

INTERVIEW GUIDE FOR GOVERNMENT INSTITUTIONS

Dear respondent,

This research aims to model the effect of **agricultural-land use polices and landscape dynamics in the Rain Forest Agro-ecological Zone of Ghana** from the crop farmers perspective and also understands various landcover changes associated with agricultural land use policies. The interview guide focusses on agricultural policies and land cover changes. There are no financial or direct personal benefits from taking part in this research; however, the results are likely to be of use by local authorities, community groups, civil society organisations, and international bodies in taking further required actions regarding landscape management. The research will reserve your right of anonymous participation and treat your information completely confidentially. Your information will be used solely for academic purposes. I believe this take about 60 minutes- 90 minutes of your time. Your co-operation plays a key role in the successful completion of this study and will be highly appreciated. Thank you.

Details

Date of interview: Occupation of interviewer:

Number of participants: Place for interview:

Age of interviewer Sex of interviewer:

What other occupation interviewer engage in and why?

AGRICULTURAL-LANDUSE POLICIES AND LANSCAPE CHANGES

1. What are the policies guiding agricultural activities in Ghana?
2. What major agricultural policies/projects/interventions have your directorate implemented in the district since your term of office to present?
3. Who were the actors of the project/interventions?
4. Does the projects specifically targeted cash crop farmers?
5. What were the purpose of the projects/interventions?
6. What activities were initiated for the farmers in the district under the projects/intervention?
7. What are the opportunities your directorate gain from this projects/intervention?
8. What weaknesses/challenges does your directorate encounter for implementing these projects/program?
9. Which other institutions does your directorate collaborate in implanting those projects or activities?

LAND USE/ LANDCOVER CHANGES IN THE DISTRICT

10. What are the specific agricultural land categorizations in the district (e.g cropland, plantations etc)?
11. What categories of crops does the farmers involved more in the districts?
12. Which of these land categories are gain more land in the district?
13. Which of these land categories are losing more in the district?

14. What are the future prospects of agricultural policies on land cover in the district?
15. What major agricultural activities influence land cover change in the district

IMPLICATIONS OF AGRICULTURAL POLICIES ON LAND USE/ LAND USE LANDCOVER

16. How does your institution regulate the activities of farmers in the district?
17. What policies guide the establishment of rubber, oil palm and cocoa plantation in your district?
18. Mention some benefits cash crop farmers are likely to derive from the project?
19. Has the project been adopted by all cash crop farmers?
20. How does the projects/intervention change agricultural output in the district?

UNIVERSITY OF CAPE COAST

FACULTY OF SOCIAL SCIENCE

DEPARTMENT OF GEOGRAPHY AND REGIONAL PLANNING

INTERVIEW GUIDE FOR CASH CROP FARMERS HEAD

Dear respondent,

This research aims to model the effect of **agricultural-land use polices and landscape dynamics in the Rain Forest Agro-ecological Zone of Ghana** from the crop farmers perspective and also understands various landcover changes associated with agricultural land use policies. The interview guide focusses on agricultural policies and land cover changes. There are no financial or direct personal benefits from taking part in this research; however, the results are likely to be of use by local authorities, community groups, civil society organisations, and international bodies in taking further required actions regarding landscape management. The research will reserve your right of anonymous participation and treat your information completely confidentially. Your information will be used solely for academic purposes. I believe this take about 60 minutes- 90 minutes of your time. Your co-operation plays a key role in the successful completion of this study and will be highly appreciated. Thank you.

Details

Date of interview: Number of participants:

Place for interview: Sex of interviewer:

Age of interviewer:

What other occupation interviewer engage in and why?

DRIVERS FOR ADOPTING AGRICULTURAL-LANDUSE POLICIES

1. What major agricultural policies/projects/interventions have your association collaborated with in the district till date?
2. How does your association contribute to Rubber / oil palm production?
3. What contribute to the adoption of ROPP/NSSP among farmers in the district
4. Does the projects specifically targeted cash crop farmers?
5. What were the reasons for adopting the projects/interventions?
6. What activities were initiated for your members in the district?
7. What benefits does your association enjoyed from NSSP/ ROPP projects/intervention?
8. What weaknesses/challenges does your association encounter for implementing these projects/program?
9. Which other institutions does your association collaborate with in the district?

IMPLICATIONS OF AGRICULTURAL POLICIES ON FOOD SECURITYAND HUMAN WELLBEING

10. How do you see the future of food production in the coming year?
11. How does the policy contribute to the wellbeing of your members in the district.
12. How do you envisage the ecological growth of the landscape in the future

APPENDIX B

RESULT ON BIVARIATE ANALYSIS OF ROPP AND NSSP

Table B1- Percentage distribution of landscape change by demographic background, policy impact the rainforest agro-ecological zone

	ROPP			NSSP		
Socio demographic	%	N 192	P-value	%	N 192	P-Value
Sex		192	0.540		192	0.540
Male		163		84.9	163	
Female	15.1	29		15.1	29	
Age			0.413			0.413
Young adult	12.5	24		12.5	24	
Middle age adult	58.9	113		58.9	113	
Old aged adult	28.6	55		28.6	55	
Religious Affiliation			0.456			0.456
Christian	62	119		62	119	
Muslim	21.9	42		21.9	42	
Traditional	16.1	31		16.1	31	
Education Level			0.062			0.062
No formal education	32.8	63		32.8	63	
Basic	50.5	97		50.5	97	
Secondary	12.5	24		12.5	24	
Tertiary	4.2	8.0		4.2	8.0	
Marital status			0.773			0.773
Single	4.2	8		4.2	8	
Married	91.1	175		91.1	175	
Divorced/separated	3.1	6		3.1	6	
Widow	1.6	3		1.6	3	
Type of crop cultivated			0.783			0.783
Rubber	66.7	128		66.7	128	
Oil palm	33.3	6.4		33.3	6.4	
Income			0.191			0.191
Low	42.7	82		42.7	82	

Middle	28.1	54		28.1	54	
High	29.2	56		29.2	56	
Years of experience			0.683			0.683
10-14 years	38.5	74		38.5	74	
15-18 years	31.3	60		31.3	60	
19- 36 years	30.2	58		30.2	58	
Farm ownership			0.188			0.188
Self	65.6	126		65.6	126	
Rent	16.7	32		16.7	32	
Family	8.3	16		8.3	16	
Friend	4.2	8		4.2	8	
Private	5.2	10		5.2	10	
Farm management			0.430			0.430
Self	66.7	128		66.7	128	
Husband	30.7	59		30.7	59	
Wife	0.5	1		0.5	1	
Children	1.0	2		1.0	2	
Non-family member	1.0	2		1.0	2	
Agriculture Inputs						
I have applied the right proportion of fertilizer			0.128			0.154
No impact	13.5	26		35.4	68	
impact	86.5	166		64.6	124	
The policy enables me to applied the right proportion pesticides			0.340			0.172
No impact	41.7	80		67.7	130	
Impact	58.3	112		32.3	62	
I have acquired higher yielding seedling breeds			0.841			0.155
No impact	24.5	47		54.2	104	
impact	75.5	145		45.8	88	
The policy has help me get access to credit			0.336			0.815

No impact	40.6	78		66.7	128	
Impact	59	114		33.3	64	
Agriculture Benefits						
I have Cultivated more crops than previous years			0.760			0.114
No impact	47.4	91		64.6	124	
Impact	52.6	101		35.4	68	
The policy has made me to change my farming pattern			0.088			0.603
No impact	81.3	156		74.5	143	
Impact	18.8	36		25.5	49	
I have acquired training in modernize agriculture technology			0.221			0.129
No impact	51.0	98		66.7	128	
Impact	49.0	94		33.3	64	
The policy has changed my farm size						0.600
No impact	81.3	156		75.5	145	
Impact	18.8	36		24.5	47	
Conservation						
The policy help to manage forest and other natural resource			0.191			0.611
No impact	71.4	137		78.1	150	
Impact	28.6	55		21.9	42	
The policy help to provide ecosystem services in the landscape			0.739			0.210
No impact	68.8	132		25.5	49	
impact	31.3	60		74.5	143	
The policy help to improve biodiversity			0.937			0.734
No impact	71.9	138		99	190	
Impact	28.1	54		1.0	2	

Infrastructure development						
New roads have been constructed and rehabilitated			0.016			0.081
No impact	53.6	103		85.9	165	
Impact	46.4	89		14.1	27	
New schools have been constructed in this community			0.978			0.844
No impact	41.1	79		96.9	186	
impact	58.9	113		3.1	6	
New hospitals facilities have been constructed and renovated			0.006			0.516
No impact	74	142		98.6	189	
Impact	26	50		1.6	3	
Water and sanitation have been improving in this community			0.221			0.197
No impact	88.5	170		96.4	185	
impact	11.5	22		3.6	7	
Livelihood						
The policy has increased my livelihood			0.320			0.038
No impact	27.1	52		55.2	106	
Impact	72.9	140		44.8	86	
The policy has improved my wellbeing			0.851			0.196
No impact	27.1	52		63	121	
Impact	72.9	140		37	71	
The policy has improved my monthly income			0.926			0.278
No impact	10.4	20		68.2	131	
Impact	89.2	172		31.8	61	

Source: Adzigbli (2022)

Appendix: C- RESULT LAND USE- LAND COVER CHANGE MODELS

Table C 1: LULC Transition Matrices of Rain Forest Agro-ecological landscape for 1991-2008, 2008-2022

		WB	SL	F	OP	BU	CL	RB	Total	GL
1991-2008										
Wetland	**143.19**	85.59	0.09	128.88	110.97	32.22	60.57	151.92	713.43	570.24
Water body	366.12	**42.39**	0	279.09	17.73	19.71	37.17	324.27	1086.48	1044.09
Shrubland	183.6	12.78	**114.21**	452.16	1260.09	122.22	934.38	681.03	3760.47	3646.26
Forest	32.49	0.9	32.04	**4999.59**	1662.84	28.17	933.57	1909.35	9598.95	4599.36
Oil Palm	851.49	102.15	264.24	2401.56	**10473.48**	395.55	4102.47	4257.54	22848.48	12374.5
Built-up	94.41	17.37	3.15	47.43	216.9	**103.86**	331.2	95.31	909.63	805.77
Cropland	194.31	24.57	23.49	563.58	3934.26	237.69	**1455.84**	1287	7720.74	6264.9
Rubber	64.71	2.97	66.24	1383.21	3062.79	90.54	1102.05	**3057.93**	8830.44	5772.51
Total	1930.32	288.72	503.46	10255.5	20739.06	1029.96	8957.25	11764.35	**55468.62**	35077.59
GG	1787.13	246.33	389.25	5255.91	10265.6	926.1	7501.41	8705.88	110936	70155.2

2008-2022	WL	WB	SL	F	OP	BU	CL	RB	Total	GL
Wetland	**1364.04**	76.41	0	6.12	270.36	123.57	35.28	54.54	1930.32	566.28
Water body	71.82	**179.82**	0	0	1.89	35.01	0.18	0	288.72	108.9
Shrubland	0.63	0	**36.36**	1.44	355.14	7.74	6.75	95.4	503.46	467.1
Forest	0.27	122.67	111.87	**5412.33**	2207.61	13.23	136.98	2250.54	10255.5	4843.17

Table C1 Continued

Oil Palm	840.69	9.09	440.55	233.28	**6400.17**	1090.98	1615.95	10108.35	20739.06	14338.9
Built-up	47.97	2.07	3.33	3.15	13.32	**902.97**	26.01	31.14	1029.96	126.99
Cropland	718.02	7.47	179.28	50.67	2270.34	1799.82	**907.65**	3024.54	8957.79	8050.14
Rubber	613.17	0.81	338.49	161.28	3658.95	181.35	762.66	**6047.1**	11763.81	5716.71
Total	3656.61	398.34	1109.88	5868.27	15177.78	4154.67	3491.46	21611.61	55468.62	34218.18
GG	2292.57	218.52	1073.52	455.94	8777.61	3251.7	2583.81	15564.5	110937	68436.4

Source: Adzigbli (2022)

Appendix: C 1

Table C 2: Transition probability matrix for LULC in the Rain Forest Agro-ecological landscape for 2022-2032

2022-2032	WL	WB	SL	F	OP	BU	CL	RB
Wetland	**0.9013**	0.0001	0.0000	0.0000	0.0095	0.0891	0.0000	0.0000
Water body	0.0000	**0.9369**	0.0000	0.0000	0.0000	0.0631	0.0000	0.0000
Shrubland	0.0000	0.0000	**0.7059**	0.0000	0.2148	0.0793	0.0000	0.0000
Forest	0.0000	0.0000	0.0000	**0.9243**	0.0755	0.0002	0.0000	0.0000
Oil Palm	0.0000	0.0000	0.0000	0.0000	**0.9975**	0.0024	0.0000	0.0000
Built-up	0.0003	0.0016	0.0000	0.0000	0.0023	**0.8794**	0.1160	0.0005
Cropland	0.0000	0.0000	0.0000	0.0000	0.0003	0.2465	**0.7506**	0.0026
Rubber	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**1.0000**

Source: Adzigbli (2022)

Table C 3:Predicted LULC change for Rain Forest Agro-ecological Zone of Ghana from 2022-2032

LULC Categories	2022 Area (ha)	2022 Percent (%)	2032 Area (ha)	2032 Percent (%)	Change 2022-2032 Area (ha)	Change 2022-2032 Percent (%)
Wetland	3779.01	6.81	3812.56	6.87	33.55	0.06
Water body	275.94	0.50	258.39	0.47	-17.55	-0.03
Shrubland	1109.88	2.00	1151.93	2.08	42.05	0.08
Forest	5868.27	10.58	5814.12	10.48	-54.15	-0.10
Oil Palm	15177.78	27.36	15141.23	27.30	-36.55	-0.07
Built-up	4154.67	7.49	4239.92	7.64	85.25	0.15
Cropland	3491.46	6.29	3409.81	6.15	-81.65	-0.15
Rubber	21611.61	38.96	21640.66	39.01	29.05	0.05

Source: Adzigbli (2022)

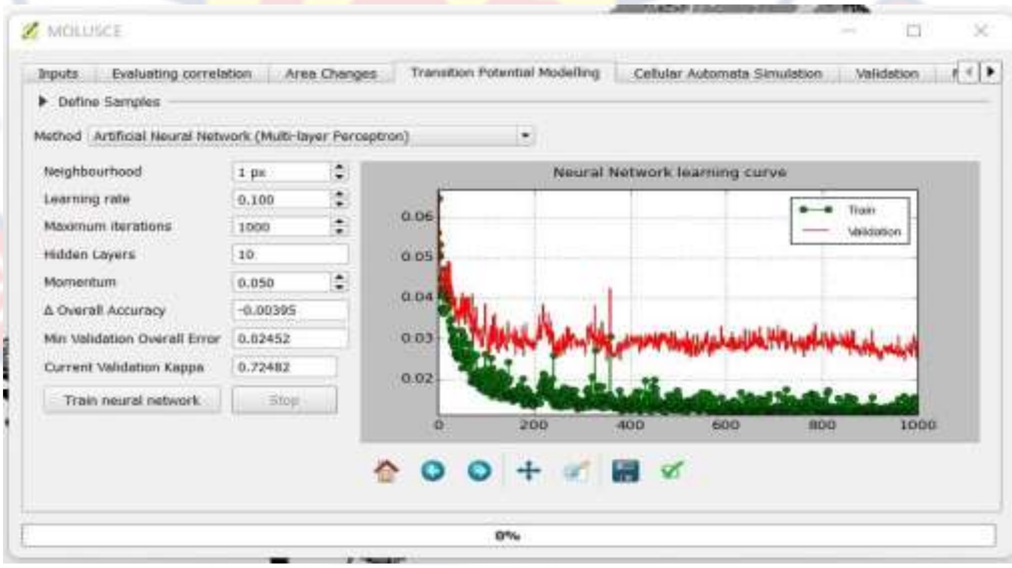

Figure C 1: Simulation result on predicted map